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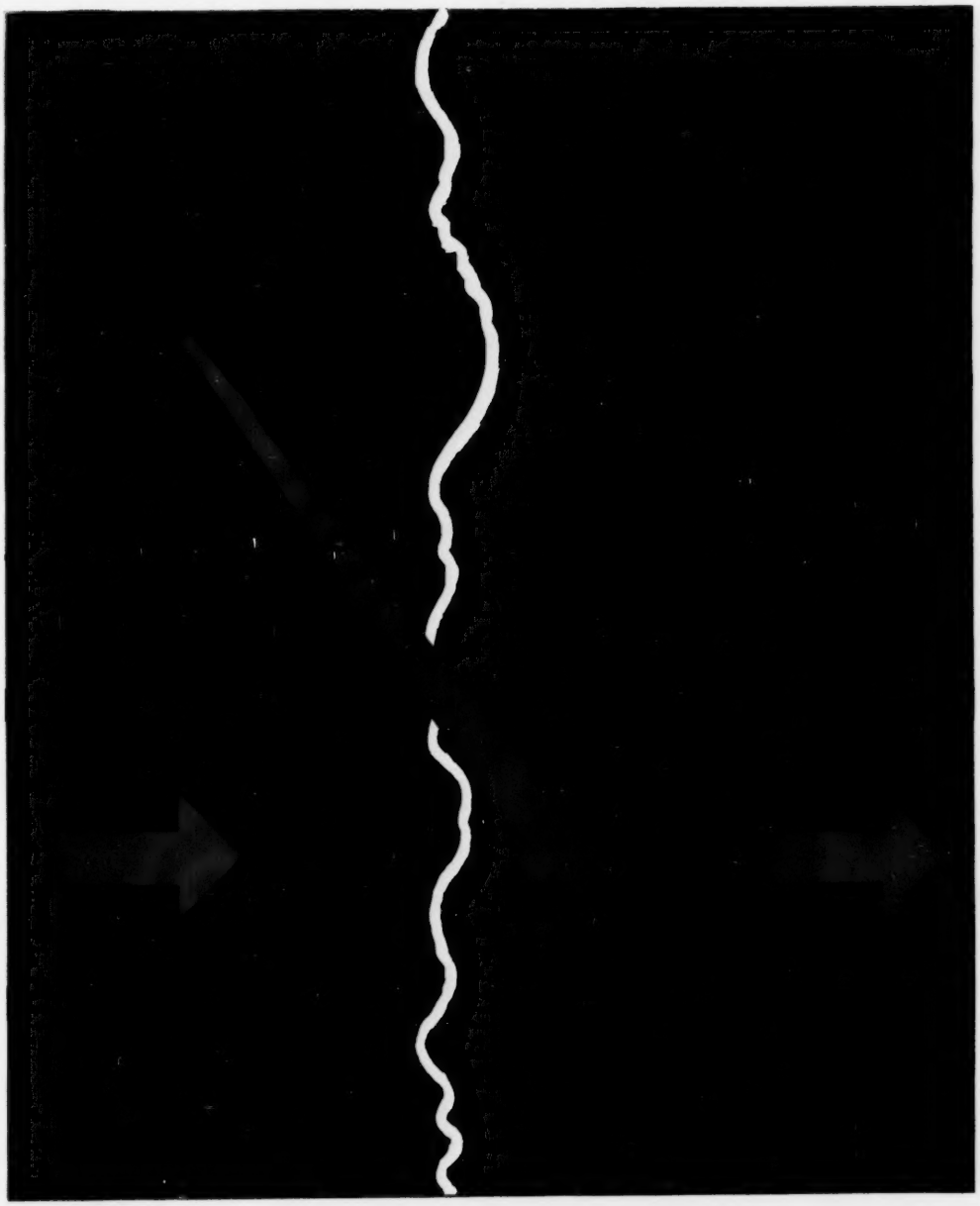

APRIL 1961

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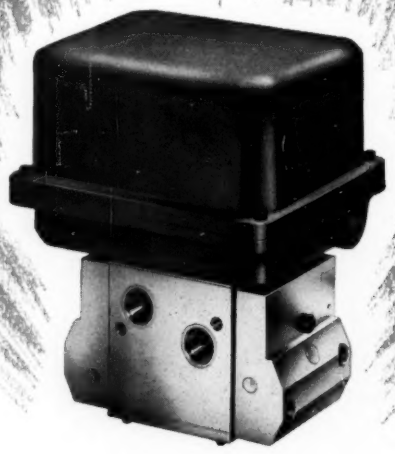

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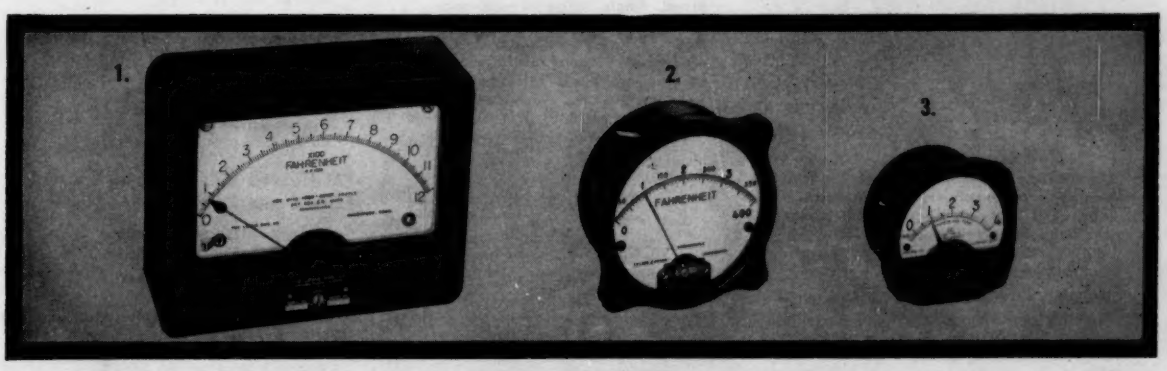

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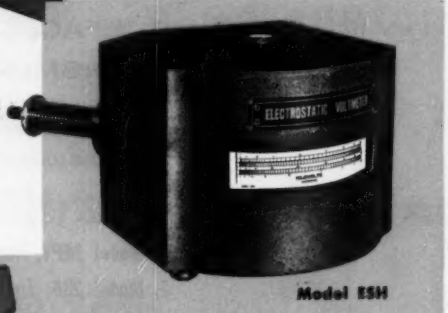

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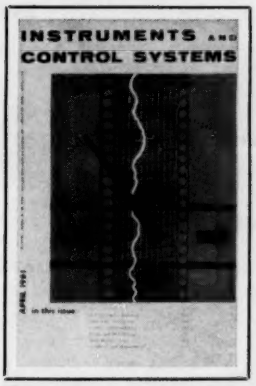

FLOW is subject for major emphasis this month, with articles on various techniques. This continues our extensive flow series.

VOLUME 34, NUMBER 4, APRIL 1961

PRINT ORDER THIS MONTH 42,900

EDITORIAL

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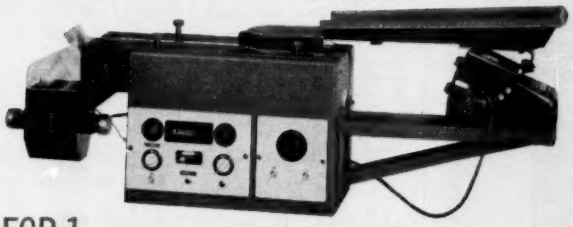

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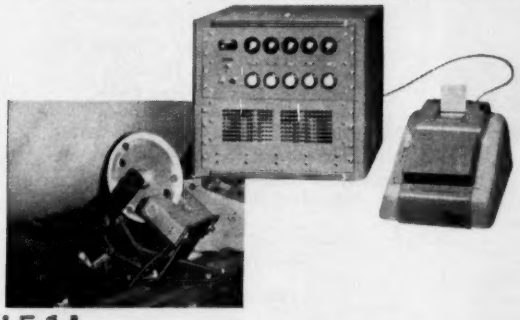

LF-1A Lineal footage measurement, electronically . . . Capable of length measuring continuous production items, i.e., paper, wire, rope, ribbon, etc.

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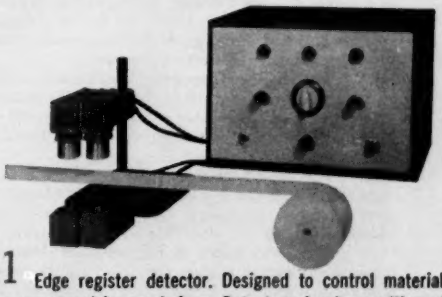
PW-5 Shown in paper making application. The counter is connected to a lineal footage measuring unit which accurately records paper production. Also provided is a "paper break detector" which will instantly shut off the machine should a web break occur.



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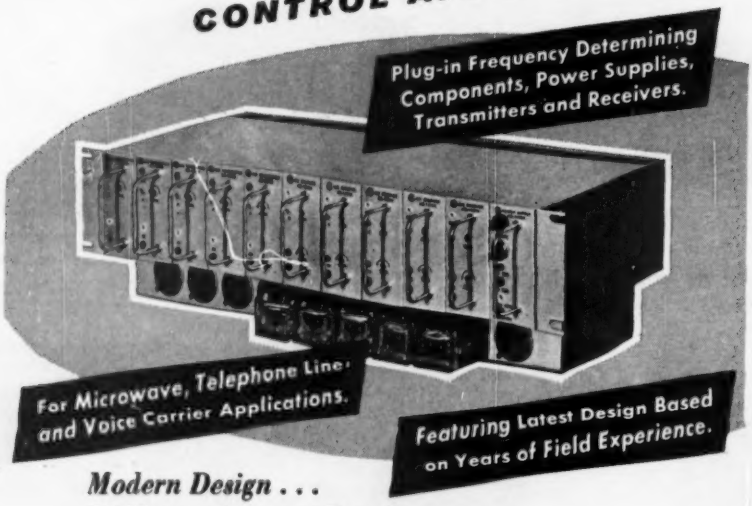
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The channel frequency determining components are also of the plug-in type and are mounted directly on the channel plug-in assembly in AM units, and adjacent to plug-in assemblies on FS units. This type of design, of course, keeps spare parts requirements to a minimum, since all plug-in cards are common to all frequencies.

The 2056 Series of AM tones were designed to meet low speed tone signalling and control requirements when low noise lines and inherently low noise communication circuits as provided by microwave and voice carrier equipments are available for transmission.

The 2056 Series of FS tones are used when ultimate reliability and high speed keying is required. They can be used in circuits which are inherently noisy and which are subject to fading conditions.

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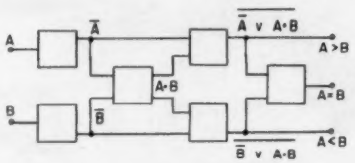
CIRCLE 5 ON READER-SERVICE CARD

I&CS LETTERS TO THE EDITOR

Editor, I&CS:

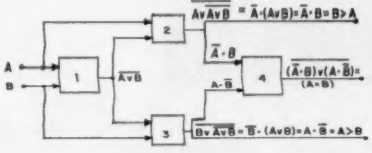
In the article, Digital Comparison by NOR Logic, J. B. Boswell, January 1961, eight NOR units are used to generate the three comparison functions A>B; A = B; A<B. It may be



of interest to readers of your symbolic logic series that six NOR functions can do the job, as shown.

M. C. McMillan
Computer Control Co.
Western Division
Los Angeles, Calif.

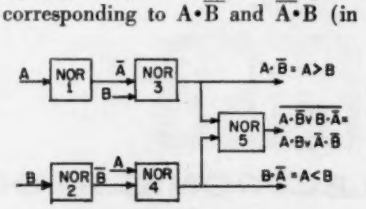
Mr. McMillan, in a following letter, also shows how to do it with 4 elements, as follows—Ed.



Editor, I&CS:

We read with great interest the article "Digital Comparison by NOR Logic" by John M. Boswell in the January issue of *I&CS*. A final circuit employing 8 NOR gates was designed to handle the complete problem. 5 NOR gates can be connected to establish full comparison of the two variables.

The condition for A = B was given in the article as $A \cdot B \vee \bar{A} \cdot \bar{B}$ and may also be expressed as $(A \vee \bar{B}) \cdot (\bar{A} \vee B)$. This expression is equal to $\overline{A \cdot \bar{B} \vee \bar{A} \cdot B}$. The latter is recognized as NORing the two inequality outputs. Thus, the signals corresponding to $A \cdot \bar{B}$ and $\bar{A} \cdot B$ (in



addition to providing inequality outputs) should be fed into a 5th NOR, whose output represent A = B.

Israel Epstein
The Clark Controller Co.
Cleveland, Ohio

Editor, I&CS:

In an article on "Digital Comparison by NOR Logic" in the January 1961 issue, John B. Boswell states that *only four* NOR elements are required for an equality comparison and shows a diagram of his circuit. As a matter of fact, the same function can be easily accomplished with just *three* NOR elements.

It can be shown by successive application of De Morgan's Theorem (July 1960 page 1141) that this is the desired function:

$\overline{\overline{A}\cdot B \;v\; A\cdot\overline{B}} = (\overline{\overline{A}\cdot B})\cdot(\overline{A\cdot\overline{B}}) = (A \;v\; \overline{B})\cdot(\overline{A} \;v\; B) = A\cdot\overline{A} \;v\; A\cdot B \;v\; \overline{B}\cdot\overline{A} \;v\; \overline{B}\cdot B = A\cdot B \;v\; \overline{A}\cdot\overline{B}$ since $A\cdot\overline{A} = B\cdot\overline{B} = 0$.

I suppose you have already learned that figures 3B and 4B are reversed in the October 1960 article.

John F. Page
Radio Corporation of America
Camden, N. J.

No we hadn't—thanks. But many persons noted the NOR technique, as these letters show:

Editor, I&CS:

Referring to the feature article "Digital Comparison by NOR Logic" on pages 62 and 63 of your January 1961 edition, the author implies by the circuit of Fig. 4 that eight NOR gates are required to achieve the three outputs:

(1) $A\cdot\overline{B}$
(2) $(A\cdot B) \;v\; (\overline{A}\cdot\overline{B})$
(3) $\overline{A}\cdot B$

If advantage be taken of the equality.

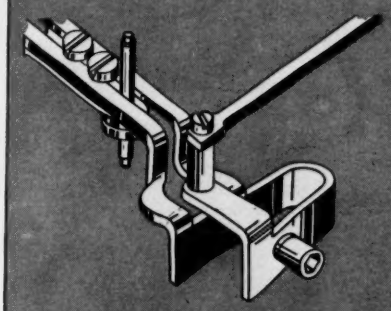
$$(A\cdot B) \;v\; (\overline{A}\cdot\overline{B}) = \overline{(\overline{A}\cdot B)\cdot(\overline{A}\cdot\overline{B})} = \overline{(\overline{A} \;v\; \overline{B})\cdot(A \;v\; B)} = \overline{A\cdot\overline{B} \;v\; \overline{A}\cdot B}$$

then output (2) could be achieved with a single NOR gate whose inputs are the outputs (1) and (3). Since outputs (1) and (3) require only two NOR gates each, the result in Fig. 4 could be achieved with a total of five NOR gates rather than eight as shown. Since this would also reduce the delay associated with output (2) by that of one gate, is this not what would be done in practice?

Larkin Scott
Consultant
Fort Worth 2, Texas

HEISE GAUGES

MICRO-SLIDE



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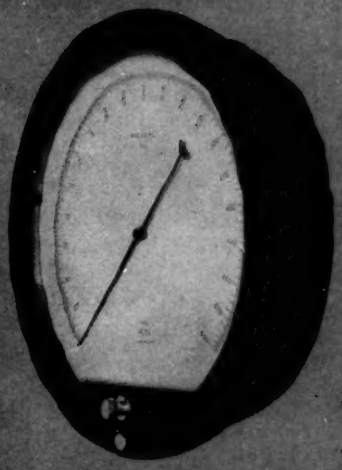
CONVENIENT PRECISION RECALIBRATION

The Micro-Slide comprises a spring loaded micrometer screw controlling the position of the link pivot. This screw may be conveniently adjusted with a standard Allen wrench. A flat spring cushions the assembly and protects the setting from shock or vibration.



Dial Sizes	FULL SCALE READING (P.S.I.)						
	0-15 to 0-5,000 inclusive	Over 0-5,000 and including 0-20,000	Over 0-20,000 and including 0-30,000	0 to 40,000	0 to 50,000	0 to 75,000	0 to 100,000
8½"	$183.50	$205.50	$238.50				
12"	$209.50	$231.50	$264.50	$275.50	$286.50	$336.50	$386.50
16"	$255.50	$277.50	$310.50	$321.50	$332.50	$382.50	$432.50

DELIVERY — 2 WEEKS FOR MOST RANGES — PRICE F.O.B. NEWTOWN

Request Catalog for SPECIAL FEATURES

HEISE BOURDON TUBE COMPANY, INC.
BROOK ROAD, NEWTOWN, CONNECTICUT, U.S.A.

CIRCLE 6 ON READER-SERVICE CARD

hays

RAMBLINGS ON INSTRUMENTATION

MUSIC

TO GET GASSED BY

(A recent letter from our man Melvin, lovable Hays representative in the southern Northeast territory, or is it the other way around?)

Dear Captain Bligh:

I herewith acknowledge receipt of two breathless missives from you. Both are barnburners, in your usual vein. Knowing your proclivity for the practical joke, I have had many a chuckle over the one about my being fired. The other is, apparently, one of your sporadic attempts to whip the sales force into a frenzy. The subject of this particular specimen of purple prose is "Hays is the leader in the continuous gas analysis field!"

While I am still reeling from this shocker, I read on to find there is an insatiable market for our Thermo-Conductivity Analyzer in slaughtering houses and missile silos. For your information, this hardly points to the road to riches for lovable old Melvin. The miserable territory to which I have been exiled has not produced a hog worth slaughtering for 20 years. And the silos hereabouts contain nothing but surplus lichee nuts . . . not a missile in the lot.

What you need, old brontausarus, is a new advertising approach. Think, man, *think!* What sells gum and soap? Jingles, that's what! I've taken the liberty of jotting down a little ditty.

Now just imagine you are a big processor with a gas analysis problem being roused by your clock radio from a peaceful slumber at 6:30 a.m. to this, with a banjo accompaniment:

If you've got gas
That's tricky to measure
The Hays Condu-Therm
Will double your pleasure.

For argon, nitrogen, NO_2
Xenon, freon—the Condu-Therm's for you.
Helium, deuterium, and ethylene, too
Acetylene, plus CO one and two.

Benzene, hexylene, a gang of methyls
(Like chloride, bromide, iodide)—and ethyls.
Pentane, propane, and here's the laugh—
Costs just a fifth of a chromatograph!

Pretty as a coffin,
Small as a C-ration
Tougher than the boss
Of the Hays Corporation.

In its black satin finish
It's a *gasser*, son!
Write for bulletin B-
Six forty-one.

I have a couple more verses that punch up such features as no moving parts, no maintenance and pinpoint accuracy. They need a little polishing but I'll shoot them on as soon as they're ready.

As an afterthought, in case that laughable note about me being fired had any connection with my last expense account, I thought I had explained that fully to Mr. Feeney. But perhaps the circumstances that led to the charter of a one-horse sleigh and the replacement of the Civil War cannon in Sauk Junction Park can best be discussed face to face the next time I am called in for an injection of home office wisdom.

Yours more in sorrow than in anger,

Melvin

P.S. If you decide to put my jingle on the air, better print an extra supply of bulletin B-641.

Phil A. Sprague
President

THE HAYS CORPORATION • MICHIGAN CITY, INDIANA

CIRCLE 7 ON READER-SERVICE CARD

Editor, I&CS:

My congratulations and thanks to the readers of my recent article on "Digital Comparison by NOR Logic" for their quick response to the fact that eight NORs were used to perform a function that could be performed by only four. This points out the highly important fact that while Boolean Algebra is a powerful tool, it depends heavily on the insight and imagination of the user.

John Boswell
Radiation, Inc.
Melbourne, Fla.

Editor, I&CS:

Your January 1961 editorial "The Engineering Shortage" pays only "lip service" to the necessity and desirability for engineers earning the respect they seek. It is pointless to *demand* a status which can only be meaningful if earned.

Engineering will be established as a profession only when engineers are recognizable by virtue of their professional conduct. Whining for restrictive legislation will not hasten the day when the practice of engineering achieves the status it deserves.

Louis E. Owen
Goodyear Atomic Corp.
Portsmouth, Ohio

Editor, I&CS:

Your January Issue had a very startling editorial, namely, "The Engineering Shortage" by D. J. Kipp.

We concur with Mr. Kipp on every point made and even to the degree. It is indeed refreshing to read an accurate and up-to-date accounting of a situation which, at the present time, has been so poorly handled and reported. There is no engineering shortage, only a shortage of good engineering management.

Garfield A. Dawe
Engineering Dept.
E. H. Sargent & Co.
Chicago 30, Ill.

Editor, I&CS:

Over eleven years ago a group of associations of engineers began what they hoped would evolve into the unification of the whole engineering profession. This dream is scheduled to fade away next month with the dissolution of the Engineers and Scientists of America.

During World War II a completely new form of engineers organization came into existence: professional collective bargaining associations. These

cropped up here and there around the country. The need for a national organization emerged.

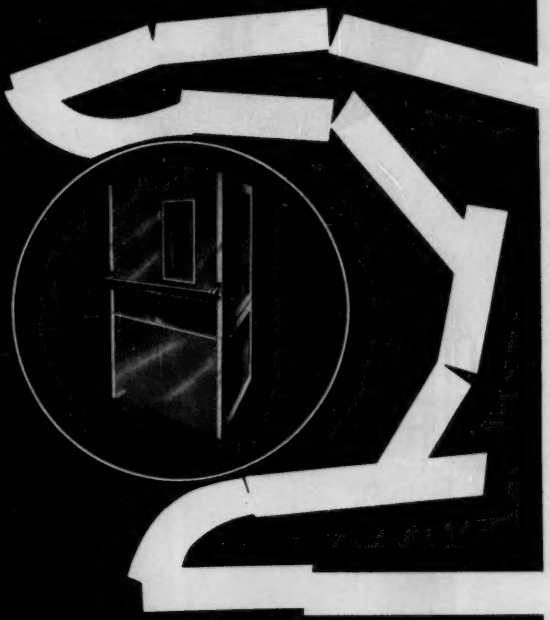
SPEEA (Seattle Professional Engineering Employees Association) was one of the prime movers behind the organization in 1949 of the National Professional Association of Engineers, Architects and Scientists, NPA for short. While this was a national organization, its membership never extended beyond the West Coast engineers associations. Almost at the same time, the engineers associations in the East began explorations among themselves toward creation of a national, to be called Council for Engineering and Scientific Employees, CESE for short. When these two groups found out about each other's existence, they amalgamated into the Engineers and Scientists of America.

Even during the preliminary exploratory conferences, difficulties arose. It happened that about half of the participating associations represented both engineers and technicians and about half represented the professionals only. Naturally, each type wanted to create the national in its own image. A compromise was finally reached which enabled the two types of associations to be affiliated with each other. However, after a few years, internal pulling and hauling caused this compromise to be reopened for discussion. The end result of this was that the half of ESA which was compromised of mixed units disaffiliated from the pure professional half. The end came at last when the RCA engineers decided to disaffiliate.

Why didn't ESA catch hold and grow? I believe that the answer flows from the most distressing of all characteristics of us engineers, namely a severe lack of any feeling of brotherhood with one another. Without the "glue" of a sympathetic community of interest, ESA had no option but to limit its activities to those specific tasks upon which we just happened to find a near-unanimity of opinion. Sadly, we came to realize that there was no such unanimity *on specifics*. Apparently ESA was "born 50 years too soon." Apparently our profession has not yet developed the collective maturity to be ready for unity on a national scale. We must gain enough experience in standing up for our own interests to develop a national consensus of appropriate employment characteristics and to develop a feeling of brotherhood with our fellow engineers.

Dan N. Hendricks, Jr.
President, SPEEA
Seattle 1, Washington

8 cu. ft. "PORTABLE"
temperature test chamber



The MC-222 is the largest precision portable temperature test chamber available . . . an economical, accurate, flexible facility for dynamically "proof-testing" electronic components.

Only the portable MC-222 offers:

- Temperature range from −100° F. to +750° F.
- Accuracy to ± 2° F. of selected temperature
- Heating and cooling rates, variable from 5° F. to 20° F. per minute
- Temperature range interchangeability
- Tests up to 1500 Diodes or 1000 Transistors
- Solid state proportional electronic control or contact Pyrometer control

For a 4-page operation manual, write:

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Statham Instruments, Inc.
12401 W. Olympic Blvd.
Los Angeles 64, California
Granite 8-0361/TWX:
West Los Angeles CAL 6602

CIRCLE 109 ON READER-SERVICE CARD

CONTROL HIGHLY CORROSIVE FLUIDS

WITH

FISHER
Bar Stock Bodies

Design 510-BP plastic bar stock body

Type 510-BA control valve

Type 511-B control valve

DESIGN AND CONSTRUCTION

	Plastic Bar Stock Bodies Design "BP"	Metal Bar Stock Bodies Design "B" or "BA"
Body Material	Penton, Type I polyvinyl chloride (PVC), or other plastics of suitable mechanical properties	Carbon steel, stainless steel, Monel, Hastelloy C, Nickel, and other bar stock metals
Body Sizes	½", ¾", 1"	½", ¾", 1"
End Connections	Screwed or socket ends	Screwed or socket ends
Valve Plug Style	Fluted plastic or metal plug with equal percentage flow characteristic	Fluted or contoured metal plug with equal percentage flow characteristic
Orifice Sizes	⅛", ⅜", ½", ¾"	¼", ⅜", ½", ¾"
Pressure Rating	Penton: 125 psi at 220° F. PVC: 125 psi at 140° F.	1500 psi at 450° F.
Available Actuators	Type 510 normally open or Type 511 normally closed diaphragm actuator	Type 510 normally open or Type 511 normally closed diaphragm actuator. Also available with Type 470 piston actuator

For additional information, see your FISHER/MAN *or write for current Bulletins*

Fisher Governor Company, Marshalltown, Iowa. Plants in Woodstock, Ont., Rochester, England. Butterfly Valve Division: Continental Equipment Co., Coraopolis, Pa.

If it flows through pipe anywhere in the world ...chances are it's controlled by.....

FISHER® Controls SINCE 1880

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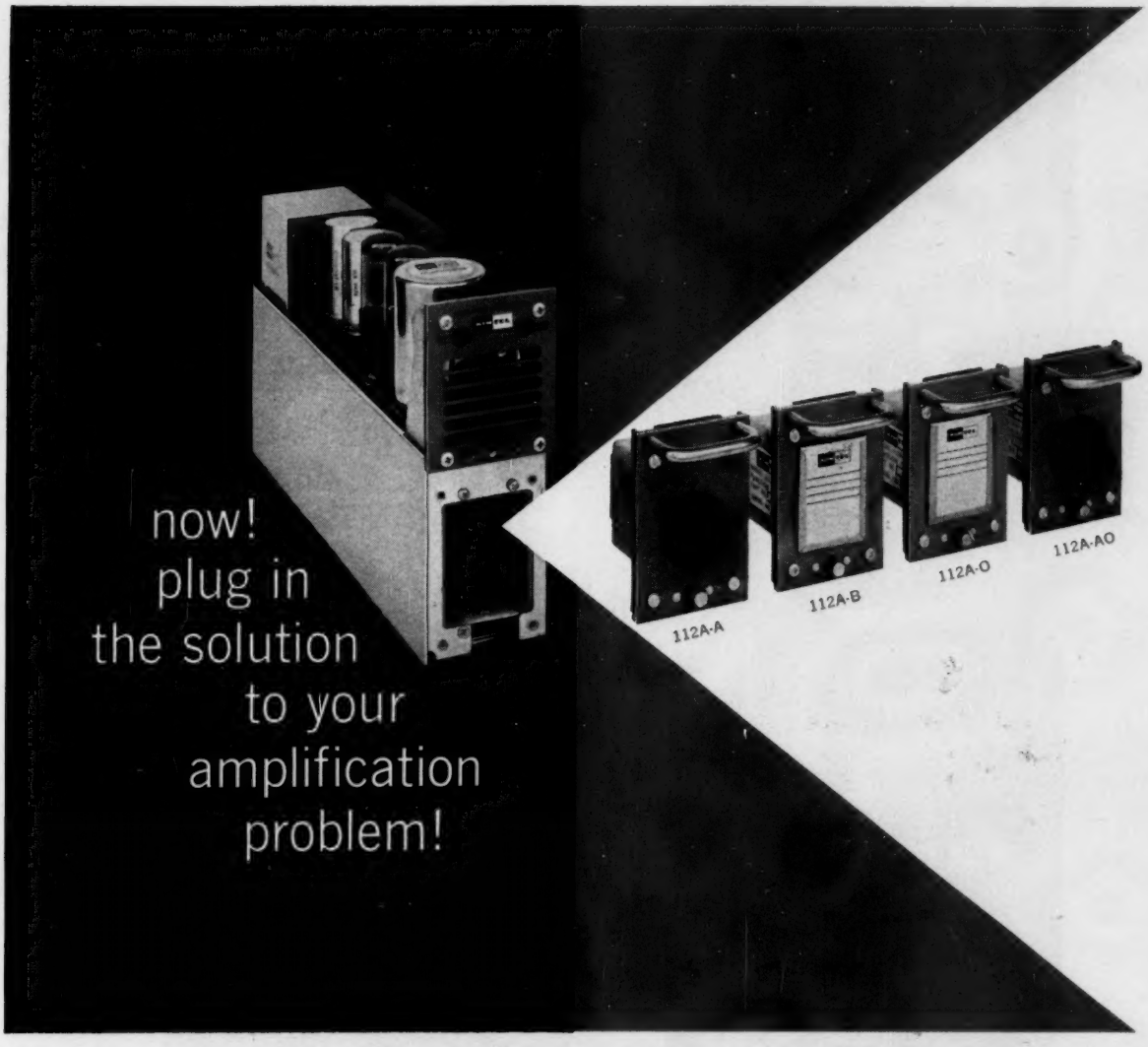


Special Plug-In Units Make KIN TEL's Wideband DC Amplifier the Basic Component in a Variety of Data Acquisition Systems. Why Not in Yours?

With a 112A-A Plug-in, the amplifier provides accurate drift-free signals at any of ten fixed gains from −20 to −1000 with a stability of ±0.1% and an accuracy within ±0.5%. A Micro-Gain control sets individual fixed gains within ±0.01%, and a 2:1 vernier control adjusts gains between fixed steps. Outputs are available up to ±45 volts or ±40 ma at an impedance less than 1 ohm, linear within 0.01% at DC and within 0.1% to 2 kc. Drift is less than 2 μv for 400 hours, and noise is less than 5 μv from DC to 750 cps, less than 12 μv to 50 kc. Bandwidth is within ±0.5% to 2 kc, ±3% to 10 kc, ±3 db to beyond 40 kc.

With a 112A-B Plug-in, the amplifier gain is fixed at +1 with an accuracy, stability, and linearity within ±0.001% at DC, ±0.1% to 2 kc. Input impedance is 10,000 megohms +100μμf at DC, 1,000 megohms +100 μμf at 2 kc. Bandwidth extends to 100 kc. Output capabilities are the same as with the 112A-A plug-in.

With a 112A-O Plug-in, the user may install resistances for any fixed gain or for +1 operation as described above. Resistive and reactive components may be installed for use as a summing amplifier, an integrator, or for other specialized operational application.

With a 112A-AO Plug-in, ten fixed gains are available with all the features described for the 112A-A unit, and in addition, an operational position is provided on the panel control for use with an external feedback network in specialized summer, integrator, or computer functions.

With any plug-in, the 112A may be used in a single-amplifier cabinet on a bench or in either a one- or six-amplifier module to fit a standard 19-inch rack. Write today for detailed technical literature or demonstration. Representatives in all major cities.

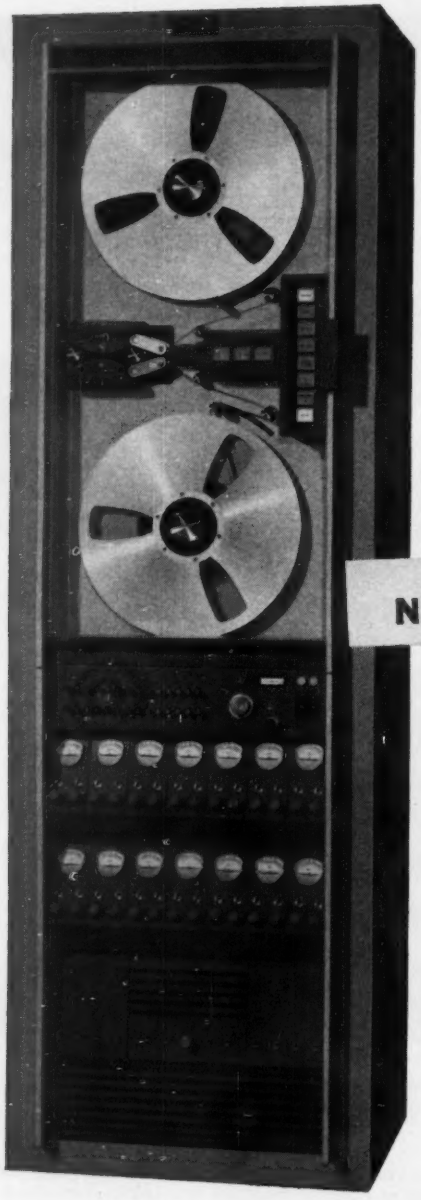
PRICES:

112A amplifier alone	$530.00
112A-A Ten-gain Plug-in	95.00
112A-B Plus-one Plug-in	85.00
112A-O Empty Plug-in	45.00
112A-AO Ten-gain/Operational	105.00
195 single-amplifier cabinet	125.00
191A Single-amplifier rack module	150.00
190 Six-amplifier rack module	295.00

5725 Kearny Villa Road
San Diego 11, California
Phone: BRowning 7-6700

KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

CIRCLE 10 ON READER-SERVICE CARD



IT'S READY

NEW THIS MONTH – 300 kc/60 ips

NEW MINCOM Model G-100 Recorder-Reproducer

Write for brochure

1. Greater dynamic range
2. 200 cps to 300 kc at 60 ips
3. All-transistorized "card system" modules
4. FM and Direct recording/reproducing
5. 14 tracks–one rack
6. Lower power requirements

3M COMPANY ... WHERE RESEARCH IS THE KEY TO TOMORROW

MINCOM DIVISION **M**INNESOTA **M**INING AND **M**ANUFACTURING COMPANY

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CIRCLE 11 ON READER-SERVICE CARD

Swagelok®

BULKHEAD CONNECTIONS

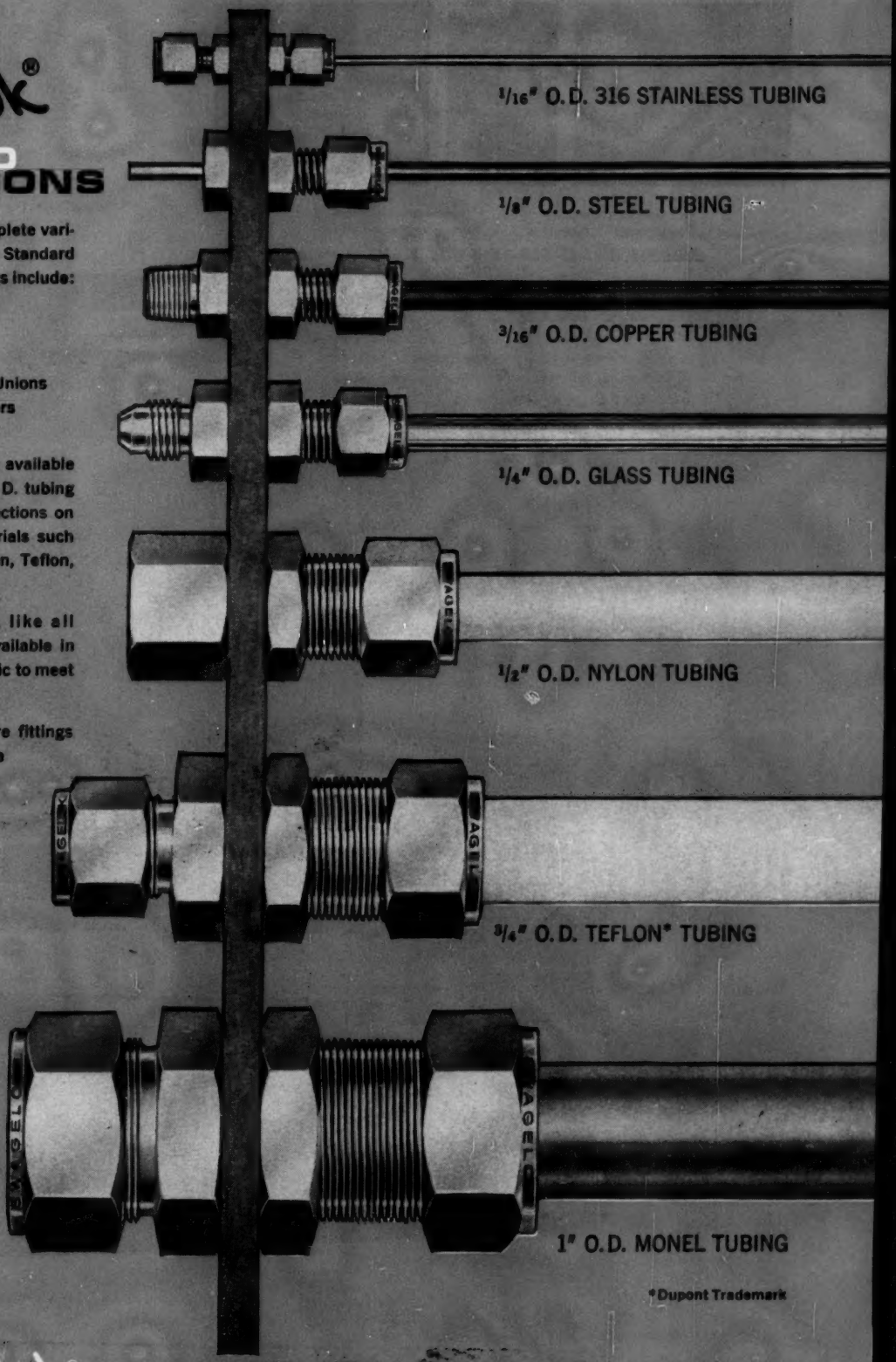
Only Swagelok has such a complete variety of Bulkhead Tube Fittings. Standard Swagelok Bulkhead Tube Fittings include:

- Bulkhead Unions
- Bulkhead Adapters
- Bulkhead Male Connectors
- Bulkhead Swagelok to AN Unions
- Bulkhead Female Connectors
- Bulkhead Reducing Unions

Swagelok Bulkhead Fittings are available in sizes for 1/16" through 1" O.D. tubing and can make leak tight connections on a wide variety of tubing materials such as stainless steel, monel, Nylon, Teflon, glass, copper, steel, etc.

Swagelok Bulkhead Fittings, like all Swagelok Tube Fittings, are available in any machineable metal or plastic to meet your particular requirements.

Remember, whether you require fittings for the simplest application or the most demanding, whether it is unusual tubing material, unusual fitting material or unusual fitting types, Swagelok Tube Fittings solve your problem.

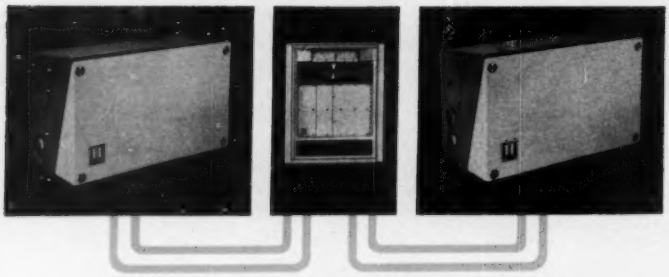


*Dupont Trademark

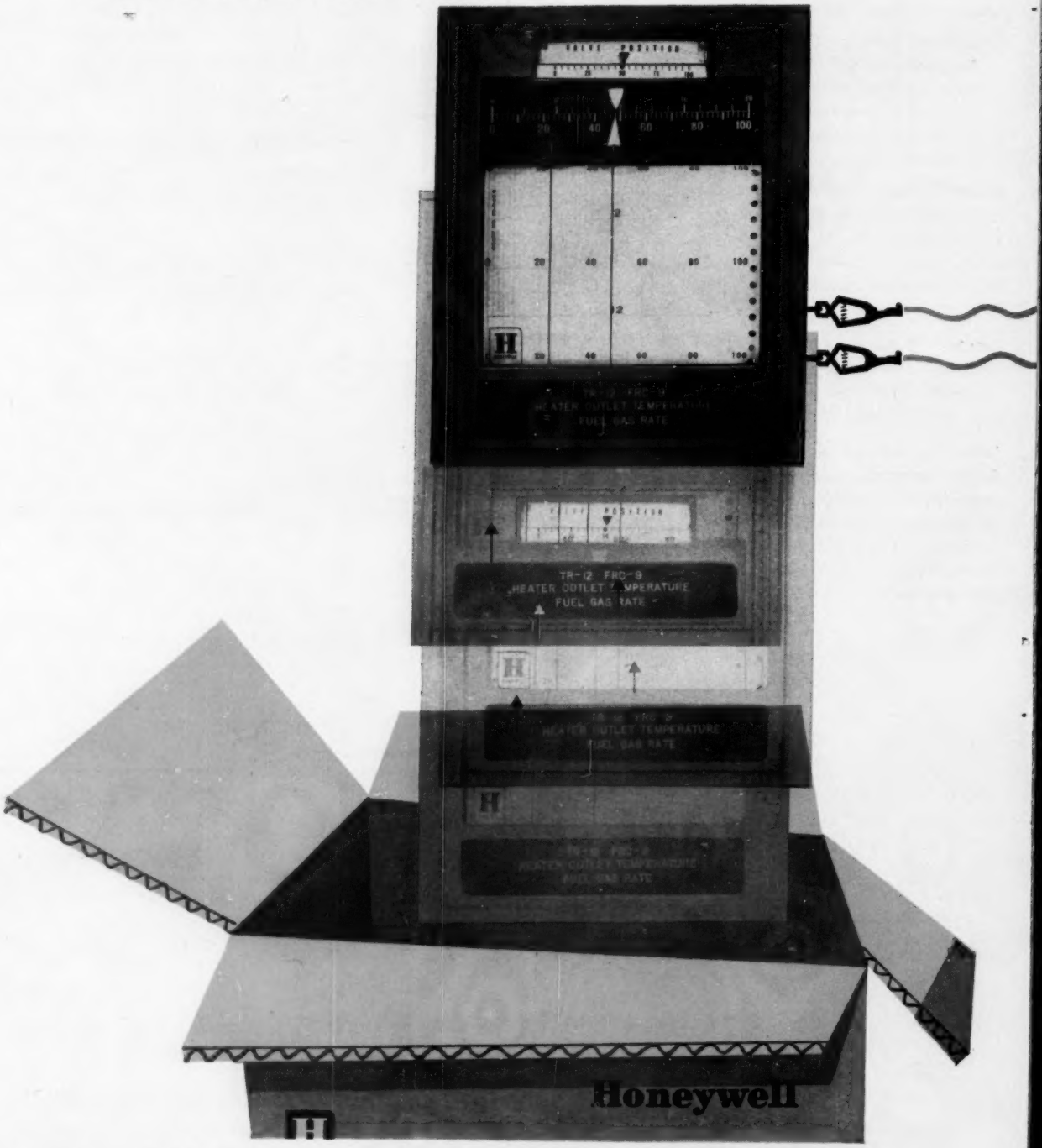
Swagelok® **TUBE FITTINGS SOLVE YOUR PROBLEMS**

CRAWFORD FITTING COMPANY • 884 EAST 140th STREET • CLEVELAND 10, OHIO
CRAWFORD FITTINGS (CANADA) LTD., NIAGARA FALLS, ONTARIO, CANADA

CIRCLE 12 ON READER-SERVICE CARD



***ElectriK Tel-O-Set*—the true 2-wire system**



This "Loop Snooper" adds to the extraordinary ease of installation and maintenance you'll find in the *ElectriK Tel-O-Set* System. It's a portable test instrument that can accurately check . . . from the control panel . . . any *Tel-O-Set* unit in the field, to make sure signals are being received and sent exactly as they should be. Or it can operate and check a recorder chassis, indicator chassis or controller on the bench, with local power. The "Loop Snooper" removes trial and error from installation and maintenance.

SIMPLEST TO INSTALL, ADJUST AND MAINTAIN

The *ElectriK Tel-O-Set* System has many features that save time in getting on stream, and keep maintenance to a minimum. For example, all process connections are isolated from the inside of *Tel-O-Set* transmitter and transducer cases, so that you can mount, pipe and wire the instruments without removing their covers. Instrument chassis can be removed for servicing without breaking any external process or electrical connections. Standardized parts and extensive use of quick-connect and plug-in design cut downtime and spare parts requirements.

No external power is required at any field-mounted *Tel-O-Set* instrument; line power is connected only at the receiver. Two-wire d-c transmission eliminates shielding and further reduces installation costs. The 4-20 milliamp signal range gives a *live* zero through the use of readily available reliable transistors.

Your nearby Honeywell field engineer can tell you how *ElectriK Tel-O-Set* advantages relate to your particular control requirements. Call him today . . . he's as near as your phone. Or write to MINNEAPOLIS-HONEYWELL, 21 Penn Street, Fall River, Massachusetts.

Honeywell

First in Control

SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

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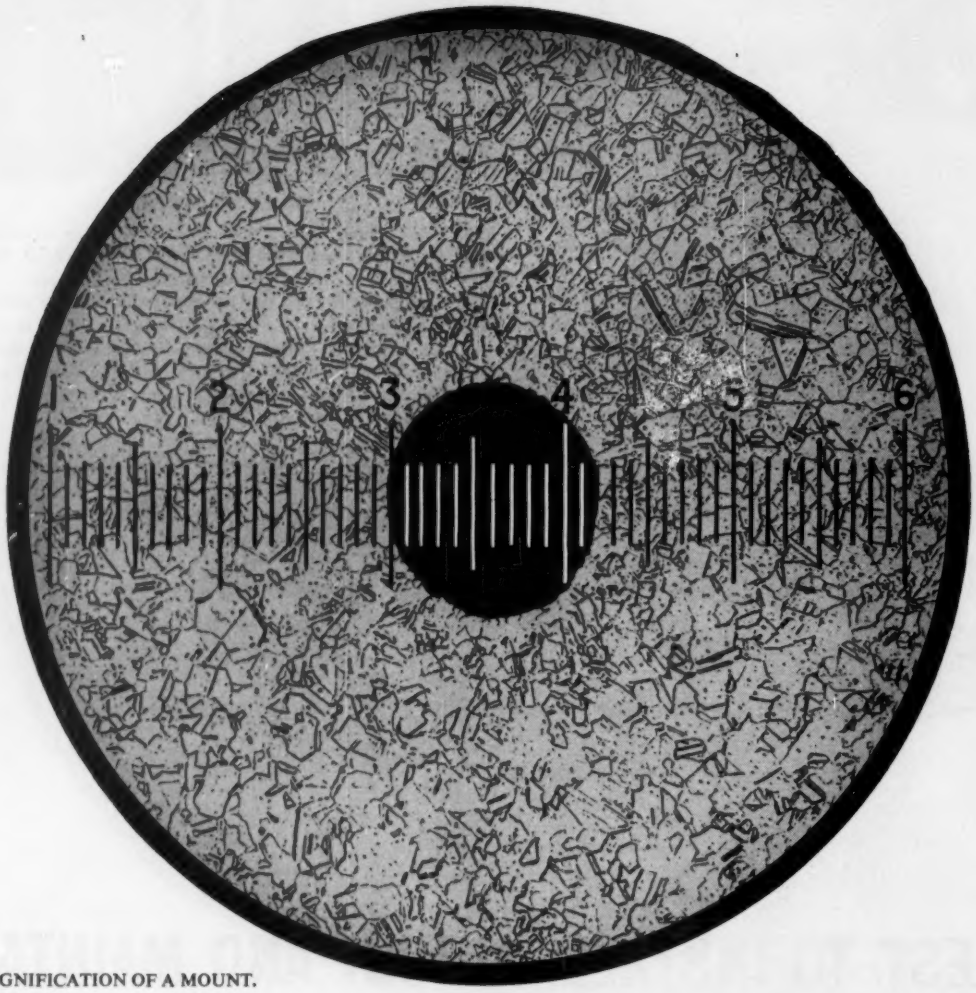


100X MAGNIFICATION OF A MOUNT.
Each division .001 in.

Capillary ID size is checked under 100x magnification

—yet this critical inspection is only 1 of 3 used to check ID of Superior capillary tubing

At Superior, in checking the ID size of capillary tubing we don't rely on only one reading from our inspection microscope, we require four. Then we double-check in two other ways—one the use of a relatively simple plug gage, the other a comprehensive flow inspection to ascertain the average ID dimension. These inspections also give you assurance of a free passage through the bore, uniformity of ID surface and a satisfactory grain structure.

Superior has spent years in the development of manufacturing processes and quality control procedures for the production of close tolerance capillary tubing. ODs range up to 3/16 in., IDs from .004 through .040 in. Analyses include Types 304, 316, 321, 347 and 446 stainless; also Monel, Inconel, nickel and carbon steel alloys. Data Memorandum No. 11 gives complete details—let us send you a copy. Superior Tube Company, 1968 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing
NORRISTOWN, PA.

All analyses .010 in. to 3/8 in. OD—certain analyses in light walls up to 2½ in. OD

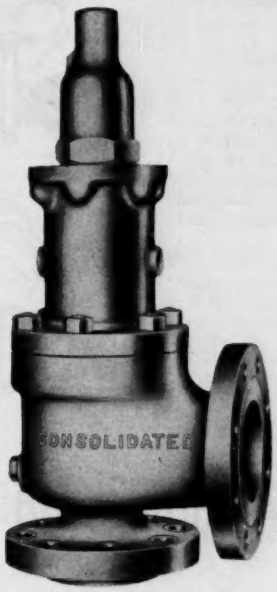
West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

CIRCLE 14 ON READER-SERVICE CARD

seal

CONSOLIDATED SAFETY RELIEF VALVE'S Sealing Bellows protects against damage from contaminants, corrosion, or viscous fluids

saves



Consolidated Safety Relief Valves are available in both Balanced Bellows and Standard designs. The Standard type has an eductor tube that effectively removes bonnet pressure.

Balanced Bellows Type Consolidated Safety Relief Valves have a durable, two-ply stainless steel Sealing Bellows that isolates and protects working parts from destructive elements in the lading fluid.

The bellows is balanced with the seating surface. Even with superimposed back pressure in the relieving system, valve performance is consistently stable and dependable. The bellows does not affect the high capacity of the valve, nor does it require change in set pressure. Even the blowdown adjustments are limited.

Additionally, Consolidated Safety Relief Valves now offer a no-leak tightness maintained by a resilient "O" Ring Seat Seal retained in the valve disc. This Seal assures tightness at operating pressures far closer to set pressure than with metal-to-metal seats alone, yet does not carry the seat load imposed by the spring. The Seal also takes piping strains much better than all-metal seating.

The Sealing Bellows and "O" Ring Seat Seal are typical of the extra quality built into Consolidated Safety Relief Valves to assure absolute protection for personnel and plant. These fine features plus flat seating and single ring construction also eliminate many maintenance problems and costs. Write for Catalog 1900 and Bulletin 1940.

MAXWELL MANNING M&M & MOORE INC. TRADE MARK

CONSOLIDATED SAFETY RELIEF VALVES

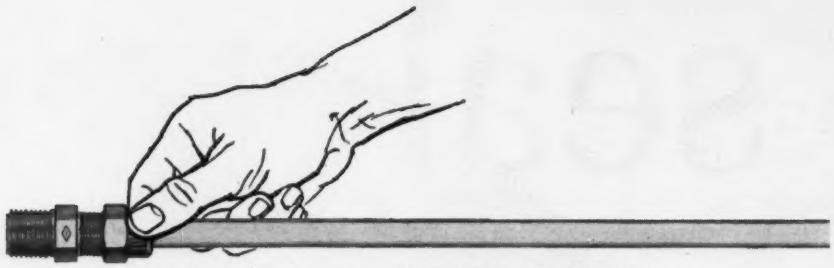
A product of

MANNING, MAXWELL & MOORE, INC.

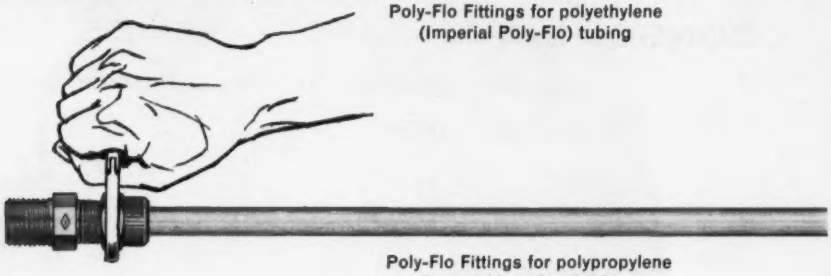
Valve Division • Tulsa, Oklahoma

Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario
Latin America: Export Division, Chrysler Building, New York, N. Y.
Europe: Manning, Maxwell & Moore, S. A., Fribourg, Switzerland

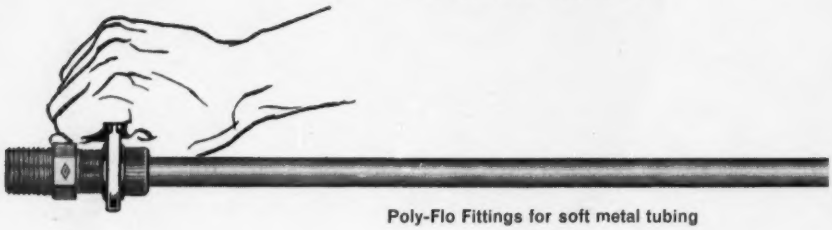
CIRCLE 15 ON READER-SERVICE CARD



Poly-Flo Fittings for polyethylene
(Imperial Poly-Flo) tubing



Poly-Flo Fittings for polypropylene
(Imperial Impolene) tubing



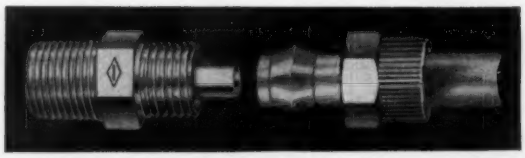
Poly-Flo Fittings for soft metal tubing

New way to simplify and save on low-pressure circuitry

Now you need only *one* fitting for low-pressure circuitry—whether you use plastic, thermoplastic or soft metal tubing. With that *one* fitting—Imperial Poly-Flo®—you economize on materials and economize on simplified assembly.

The unique design of Poly-Flo Fittings eliminates inconvenient inserts. Assembly is quick and easy. Material and time costs are lowered. Fittings hold beyond burst pressures of the tubing, assuring dependable assemblies for instrumentation as well as many hydraulic and pneumatic circuitry applications.

When used with polyethylene tubing, Poly-Flo Fittings are simply finger-tightened, saving additional time and money. No tools except a wrench are ever needed with other tubing.



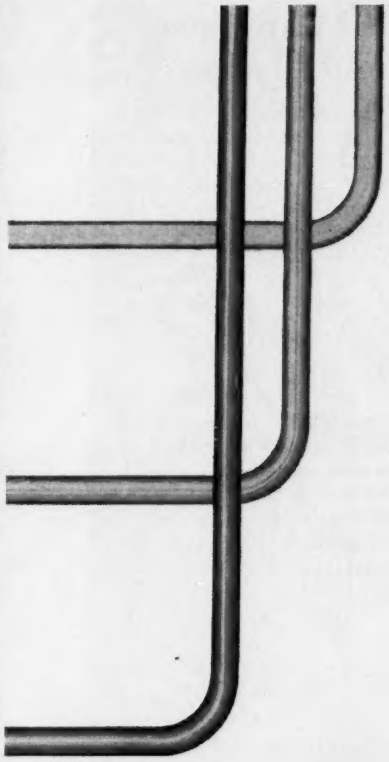
POLY-FLO

IMPERIAL EASTMAN

Imperial-Eastman Corporation General Offices: 6300 West Howard Street, Chicago 48, Illinois

Imperial-Eastman Corporation (Canada) Ltd., Barrie, Ontario • Imperial-Eastman, S.A., Apartado Postal 26544, Mexico 13, D.F.

CIRCLE 16 ON READER-SERVICE CARD

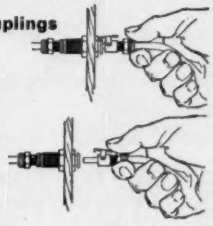


Poly-Flo Fittings available in variety of styles, sizes

Poly-Flo Fittings include straight unions, connectors, half unions, bulkhead unions, reducing adapters, elbows, tees and Kwik-Connect valves. Sizes to ½ in., tube o.d. For complete information, write for Bulletin 3025-F.

Kwik-Connect Couplings

Push . . . the fitting snaps together, forming a reliable, pressure-tight connection with 2-way flow. Click . . . it's disconnected—flow instantly cut off.



FITTINGS

IMPERIAL — EASTMAN

IQS EVENTS

April 19-21

Seventh Annual Southeastern ISA Conference and Exhibit, Charlotte, North Carolina. For information write Eugene B. Finch, Route 2, Box 673-C, Charlotte 9, North Carolina.

April 19-21

Thirteenth Annual Southwestern IRE Conference & Electronics Show (SWIRECO), Memorial Auditorium and Baker Hotel, Dallas, Texas. For information write Frank J. Ocnaschek, Collins Radio Co., Richardson, Texas.

April 25-27

Ninth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Okla. For information write Prof. Chas. F. Cameron, School of Electrical Engineering, Oklahoma State Univ., Stillwater, Okla.

April 26-28

Seventh Regional IRE Technical Conference and Electronic Exhibits, Westward Ho Hotel, Phoenix, Ariz. For information write H. W. Welch, Jr., Box 1417, Scottsdale, Arizona.

April 30-May 4

National Aero-Space Instrumentation Symposium, Adolphus Hotel, Dallas, Texas. For information contact: W. J. Gabriel, Convair Div., General Dynamics Corp., Ft. Worth, Texas.

May 2-4

IRE-AIEE Electronic Components Conference, Jack Tar Hotel, San Francisco, Calif. For information write Daniel Breading, Fairchild Semiconductors Inc., Palo Alto, Calif.

May 8-10

Thirteenth Annual National IRE Aerospace Electronics Conference, Biltmore and Miami Hotels, Dayton, Ohio. For information write NAECON Publicity, 4663 Hedgewood Ave., Dayton 16, Ohio.

May 8-10

National ISA Power Instrumentation Symposium, LaSalle Hotel, Chicago, Ill. For information write Meeting Manager, Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa.

May 9-11

Western Joint Computer Conference and Exhibit, Ambassador Hotel, Los Angeles. For information write Dr. Walter F. Bauer, Ramo-Wooldridge, a division of Thompson Ramo-Wooldridge, Inc., 8433 Fallbrook Ave., Canoga Park, Calif.

May 9-17

International Exhibition Measurement, Control, Regulation, Automation (Mesucora) Centre national des industries et des techniques, Paris, France. For information write Mesucora, Service Propagande, 40 rue du Colisee, Paris 8°, France.

May 10-12

Pulp and Paper Instrumentation Symposium, Northland Hotel, Green Bay, Wis. For information write Meetings Manager, Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa.

May 22-24

National Telemetering Conference, Hotel Morrison, Chicago, Ill. For information write Jack Becker, Dept. 32-29, AC Spark Plug Div., General Motors Corp., Milwaukee 1, Wis.

May 22-24

Fifth AIEE-IRE National Symposium on Global Communications (GLOBECOM V), Hotel Sherman, Chicago, Ill. For information write Donald C. Campbell, I.T.T.—Kellogg, 5959 S. Harlem Ave., Chicago 38, Ill.

May 23-25

Symposium on Large Capacity Memory Techniques for Computing Systems, Department of Interior Auditorium, Washington, D.C. For information write Josephine Leno, Code 430A, Office of Naval Research, Washington 25, D.C.

June 4-9

Ninth Annual ASTM Meeting on Mass Spectrometry, Hotel Sherman, Chicago, Ill. For information write Dr. George Crable, Gulf Research Center, Box 2038, Pittsburgh 30, Pa.

June 6-8

ISA Summer Instrument-Automation Conference & Exhibit, Royal York Hotel and Queen Elizabeth Hall, Toronto, Ont., Canada. For information contact Instrument Society of America, Wm. H. Kushnick, 313 Sixth Avenue, Pittsburgh 22, Pa.

June 9-17

International Chemical Engineering Exposition and Congress ACHEMA, Frankfurt am Main, West Germany. For information write Chicago Section American Chemical Society, 86 East Randolph St., Chicago 1, Ill.

June 12

ISA-APCA Air Pollution Instrumentation Symposium (with the June 11-15 Annual Meeting of the Air Pollution Control Association), Hotel Commodore, New York, N. Y. For information write Meetings Manager, Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa.

June 13-16

Biennial International Gas Chromatography Symposium, Kellogg Center, Michigan State University, East Lansing, Mich. For information write Meetings Manager, Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa.

ICS NEWS

PRECISION POTENTIOMETER MFRS. ASSN. (27 East Monroe St., Chicago 3, Ill.) recently formed, formalized plans for 1961 activities during its Annual Meeting held in Phoenix. Main activities mapped out include, that the *Government and Industry Specifications Committee* will continue its work to analyze MIL-R-12934B. The *Standards and Nomenclature Committee* will formalize proposals for procedures to measure temperature coefficients, and to measure linearity. The *Reliability and Applications Committee* will survey reliability problems.

Companies that have officially become members of PPMA include: Analogue Controls, Inc.; Borg Equipment Division; Bourns, Inc.; Clarostat Mfg. Co., Inc.; Daystrom, Inc.; DeJur Amsco Corporation; Edcliff Instruments; Fairchild Controls Corporation; Gamewell Company; General Controls Company; Helipot Division, Beckman Instruments, Inc.; International Resistance Co.; Markite Corporation; New England Instruments Co.; George Rattray & Co., Inc.; Spectrol Electronics Corp.; and Technology Instruments Corp.

CASE INSTITUTE OF TECHNOLOGY will have in its summer study program a course on Digital Control Systems Engineering (June 19 to June 30, 1961). For more information address Herbert B. Schultz, Jr., Manager of Special Programs, Case Institute of Technology, University Circle, Cleveland 6, Ohio.

ISA Recommended Practice 26.4 on "Dynamic Response Testing of Final Control Elements and Actuators" has been prepared in draft form to permit reviewing and commenting before its publication. Available from F. H. Winterkamp, E. I. duPont deNemours & Co., Inc., P. O. Box 993, Charleston 24, W. Va.—**Recommended Practice ISA-RP16.4** covers nomenclature and terminology for extension- type variable-area meters (rotameters). Available from Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa., 50c to ISA members and 75c to non-members.

Gordon Research Conferences

The Gordon Research Conferences for 1961 will be held from 12 June to 1 September at Colby Junior College, New London, New Hampshire; New Hampton School, New Hampton, New Hampshire; Kimball Union Academy, Meriden, New Hampshire; and Tilton School, Tilton, New Hampshire. The Conference comprises an informal type of meeting consisting of scheduled lectures and discussion groups.

Attendance at each Conference is limited to approximately 100 conferees. Requests for attendance at the conferences, or for additional information, should be addressed to W. George Parks, Director, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island. From 12 June to 1 September 1961 mail for the office of the Director should be addressed to Colby Junior College, New London, New Hampshire.

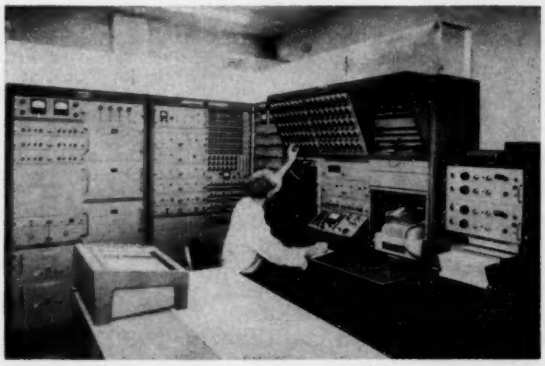
11th General Conference on Weights and Measures

PARIS, FRANCE—The Conference confirmed the action of the International Committee on Weights and Measures in defining the *second of time* as 1/31,556,925.9757 of the tropical year 1900 instead of 1/86,400 part of the mean solar day.

The *temperature* of a mixture of ice and water at normal atmospheric pressure, used as a standard for temperature measurements for many years, was abandoned and replaced by the equilibrium temperature of ice, water, and water vapor, which is more accurately reproducible.

MIT will present a special summer course on Experimental Techniques in measurements of displacement, strain, force, torque, velocity, acceleration, flow, temperature, wear and surface characteristics. Time: June 13 through 23. More information may be had from N. H. Cook, Associate Professor in charge of Materials Processing Division, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge 39, Mass.

COMPUDYNE's new computer facility, built by *Electronic Associates*, more than doubles its old system and

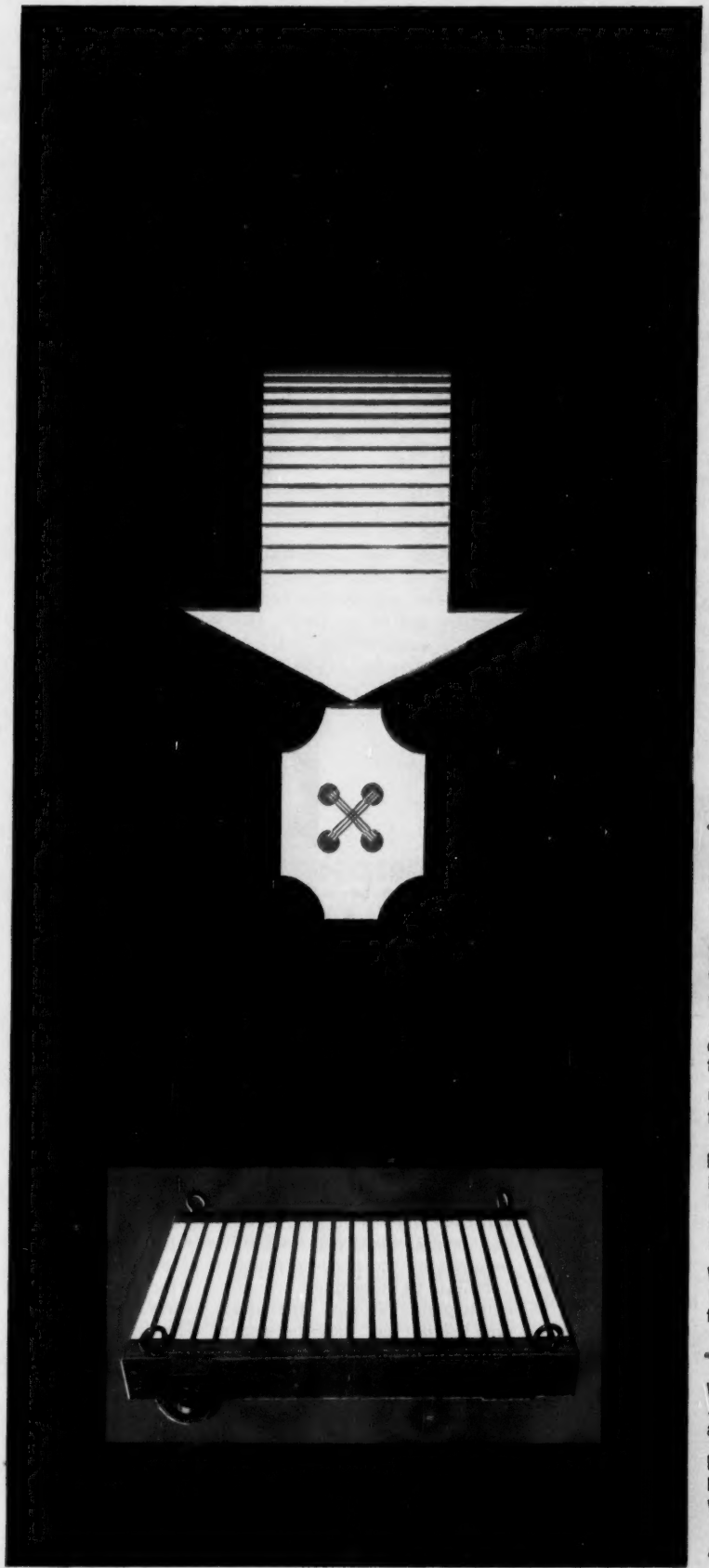


enables it to solve highly complex problems such as wind-tunnel or pipe-line-compressor surge control, multi-stage process interrelationships in refineries and other chemical process plants, etc.

WESTERN JOINT COMPTER CONFERENCE in 1961 has been scheduled for May 9-11 at the Ambassador Hotel in Los Angeles.

FISHER GOVERNOR CO has produced a 16-mm sound-color film "Napoleon's Gun Barrels," which describes the growth of the gas industry from its beginning. To borrow a copy without charge contact your Fisher sales representative.

DAYSTROM SYSTEMS and **UNIVERSAL OIL PRODUCTS CO.** have joined forces, resulting in a computer-operated control system for the entire petroleum and petrochemical industries. It has proved successful in pilot-plant operation.



ASEA

builds world's largest load rated cell... 7 million pounds

Rated at 7,000.000 pounds, the largest capacity Press ductor, now being built in Sweden for a U. S. steel mill, measures 25"x24"...and is only 3" thick. Its output voltage is sufficient to drive an instrument or relay with no need for amplifier.

ASEA Pressductor's error of measurement, under normal conditions, is within ±1% of actual value between 10-100% nominal load. Under ideal conditions, even better accuracies may be obtained.

In service at many modern rolling mills, ASEA Pressductors are proving their suitability for the most difficult applications where dirt, dust and moisture problems exist. ASEA Pressductors withstand considerable overload without damage...are free of hysteresis (particularly important in automatic system regulation) ...resist lateral forces...offer interchangeability of units (no recalibration necessary)...and both calibration and performance are unaffected by age.

The superiority of ASEA Pressductors is now being proved in the following applications:

Measurement of:
rolling forces and strip tension in rolling mills ■ propulsion forces in ships ■ web tension in paper machines ■ column pressures in buildings

Weighing of:
coils in rolling mills ■ ore, etc., in hoppers ■ loads on cranes, hoists, elevators ■ charges in electric furnaces

Overload protection:
for transportation and handling equipment

Future planned applications include:

Measurement of:
rocket test stand thrust ■ tension of conveyor belts ■ torque in sluice gate hoists ■ pull in carrying cables and drag lines ■ drilling pressures for deep drilling

Weighing of:
trucks, railway cars, aircraft, etc., on loading platforms

Write for detailed descriptions of ASEA Pressductors and the advantages they offer to your specific job application.

U. S. Sales and Service: ASEA ELECTRIC, INC.
East Coast: 500 Fifth Avenue, New York 36, N. Y.
West Coast: 55 New Montgomery Street, San Francisco 5, California

"ASEA world pioneer in electrical products for industry"

CIRCLE 17 ON READER-SERVICE CARD

NEW APPLICATIONS

BAILEY METER COMPANY has received a contract for a Bailey 720 Economic Load Control System that will control frequency and/or tie-line load as well as distribution of load on incremental rate basis between eight generating units at three plants of Columbus and Southern Ohio Electric Company. (Bailey Meter Co., 1041 Ivanhoe Rd., Cleveland 10, Ohio).

CIRCLE 186 ON READER-SERVICE CARD

ROBERTSHAW-FULTON CONTROLS CO., Aeronautical & Instrument Div., has supplied the Level-Tel continuous level indication system for the Shell Chemical Corporation Latex plant in Torrance, Calif., monitoring the copolymerization of synthetic rubber's two basic ingredients—butadiene and styrene. (Robertshaw-Fulton Controls Co., Santa Ana Freeway & Euclid Ave., Anaheim, Calif.)

CIRCLE 187 ON READER-SERVICE CARD

AMERICAN ELECTRONICS, INC., Special Instrumentation Systems Div., has installed (in seven American cities) "Arbitron," an electronic computing device which instantaneously measures the audience tuned to any television program at any given moment.

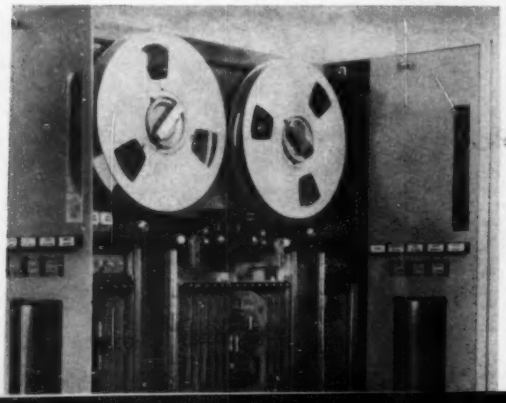
AERO SERVICE CORP. (210 E. Courtland St., Phila. 20, Pa.) has created a new, lower-cost method of photo-recording highways from the driver's point of view. The

recording Photo/File system employs a specially modified 16-mm camera to provide a sequential record of the highway at regular 1/100th-mile or 53-foot intervals.

CIRCLE 188 ON READER-SERVICE CARD

Army Gets Special Digital Tape Handler

REDWOOD CITY, CALIFORNIA.—An advanced magnetic-tape transport, designed to be compatible with all members of the Army's FIELDATA family of computers, has been developed by Ampex Military Products Company (P. O. Box 727, Redwood City, Calif.) a subsidiary of Ampex Corporation. Completely transistorized, and designed to be van-mounted, eleven of these units are being delivered to the U. S. Seventh Army in Germany as part of the new Army Data Processing System (ADP). It will be used for both clerical and high-speed computational work.



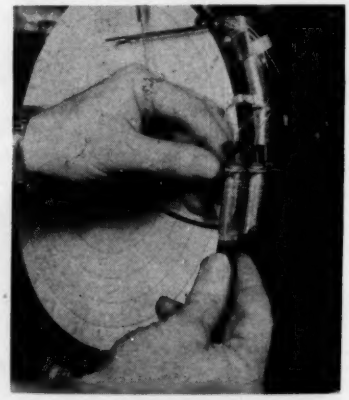
The Army asked for a reliability rate of 10^{10} characters. This is approximately one undetected error in 1,000 reels of tape. Ampex achieved this goal under the most adverse simulated conditions, by using seven support channels for seven channels of information.

CIRCLE 189 ON READER-SERVICE CARD

Meter Marking Device

CAMDEN, N. J.—Substantial savings in service time and costs have been effected, and recording reliability has been improved by a new ink-cartridge meter marking device now undergoing field tests at Du Pont's Chambers Works, Deepwater Point, N. J., and in other industrial plants employing up to several thousand recorders and controllers.

At the Du Pont plant, test installations were made in the spring of 1960 on both inside and outdoor vertical dial meters, recording water consumption, steam consumption, and temperatures. One of the installations was made in a small wooden shack built directly over an open water trough. All installations have operated satisfactorily, with minimum servicing, under varying conditions of heat, cold, and humidity.



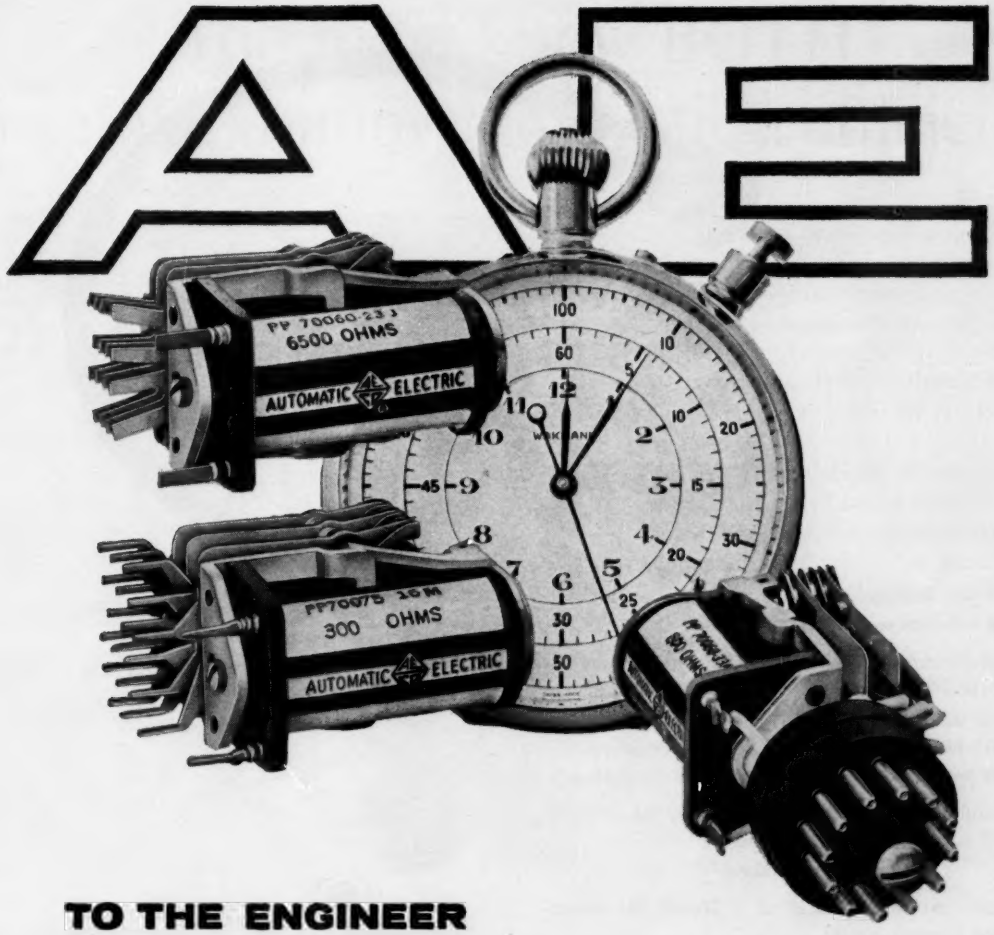
Marking device being inserted in a Hagan recorder.

Developed by Esterbrook Pen Company, Delaware Ave. & Cooper St., Camden, N. J., the new marking device substitutes a capillary system drawing ink from a disposable cartridge for the conventional manually-filled, open-bucket type system. Because the cartridge contains sufficient ink for up to several months of operation, fillings several times per week or even per day previously required by the open-bucket systems are eliminated.

Failure to mark due to clogging of the ink flow is also eliminated, since dust, dirt, and moisture that cause clogging cannot get into the system. The ink cartridge is sealed until punctured by the capillary tube when inserted for use. The transparent plastic cartridge assures visibility of the ink supply at all times. Replacement of an exhausted cartridge takes only a few seconds.

Esterbrook's meter marking device is readily adaptable to all existing-type recorders—circular, strip, miniature, and plotter—and has been adopted as standard on Hagan Ring Balance Recorders manufactured by Hagan Chemical & Controls, Inc., Pittsburgh, Pa.

CIRCLE 190 ON READER-SERVICE CARD



TO THE ENGINEER

looking for a quick connection

Engineers out to cut costs at no expense of reliability can count on dramatic savings in assembly and wiring time by designing around AE Class E relays with quick-connect terminals.

Series EQPC is designed for direct insertion into printed circuits. Series EQTT, with Taper-Tab terminals, provides firm, high-conductivity connections without soldering.

AE also supplies Class E relays prewired for plug-in – with standard 8- to 20-prong octal plugs. Where additional relay protection is essential, the plug-in types are available in hermetically sealed containers or with dust-tight housings and hold-down brackets.

The AE Class E relay is a miniaturized version of the premium-quality Class B, with many of its best features. Perfect contact reliability exceeding 200 million operations is common.

AE is also equipped to supply wired and assembled, custom-built control units, *or to help you develop complete systems.*

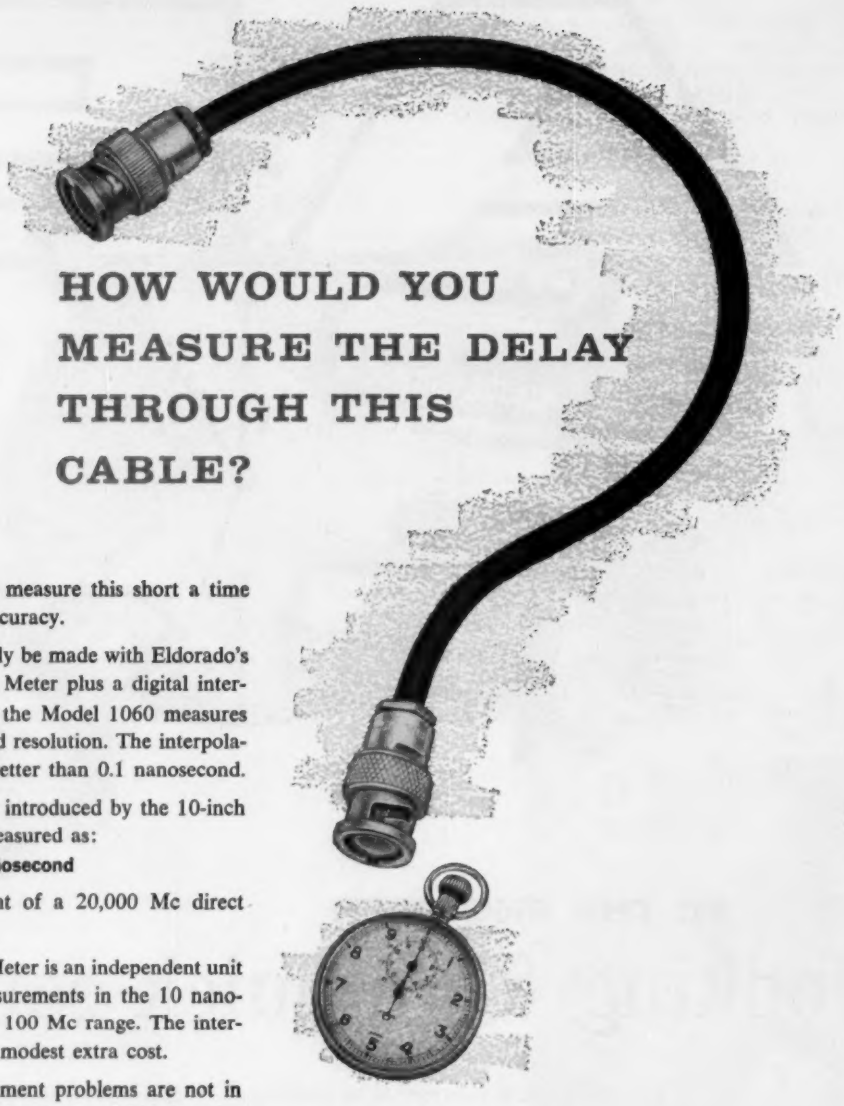
Want details? Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1702-E on *Relays for Industry,* and the new 32-page booklet on *Basic Circuits.*

AUTOMATIC ELECTRIC GENERAL SYSTEM

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

CIRCLE 18 ON READER-SERVICE CARD



HOW WOULD YOU MEASURE THE DELAY THROUGH THIS CABLE?

Until now it was impossible to measure this short a time interval with sub-nanosecond accuracy.

Now, this measurement can easily be made with Eldorado's new Model 1060 Time Interval Meter plus a digital interpolator. Solid state throughout, the Model 1060 measures time interval with 10 nanosecond resolution. The interpolator improves the resolution to better than 0.1 nanosecond.

Using this equipment, the delay introduced by the 10-inch cable plus its connectors was measured as:

1.43 ±.05 nanosecond

This resolution is the equivalent of a 20,000 Mc direct counting time interval meter!

The Model 1060 Time Interval Meter is an independent unit suited for all time interval measurements in the 10 nanosecond range or counting in the 100 Mc range. The interpolator accessory is available at modest extra cost.

Even though your time measurement problems are not in the area of cable delays, but rather in the fields of radar ranging and calibration, high speed velocity measurement, rocket sled timing, shock waves, ultra-high speed photography, satellite tracking, ballistic missile studies, or any field where data is gathered in the form of a time interval measurement, this new technique may offer the solution you have been seeking.

For specific details on the Model 1060 and the interpolator, and for assistance in applying them to *your* problems, contact your Eldorado engineering representative or drop us a line at the factory. Please address Dept. 54.

BASIC DATA MODEL 1060 COUNTER-TIME INTERVAL METER

Time Interval Meter

MAX. TIME INTERVAL: 10 seconds • RESOLUTION: 10 nanoseconds
TYPICAL START/STOP PULSE REQUIREMENT: −4 volts into 50 ohms
OSCILLATOR STABILITY: 0.0001% • READOUT: Nixie inline and output for printout.

Counter

STORAGE: 10^9 counts • MAX. COUNTING RATE: 100 Mc/s
TYPICAL INPUT PULSE REQUIREMENT: +4 volts into 50 ohms
DELIVERY: 45 days.

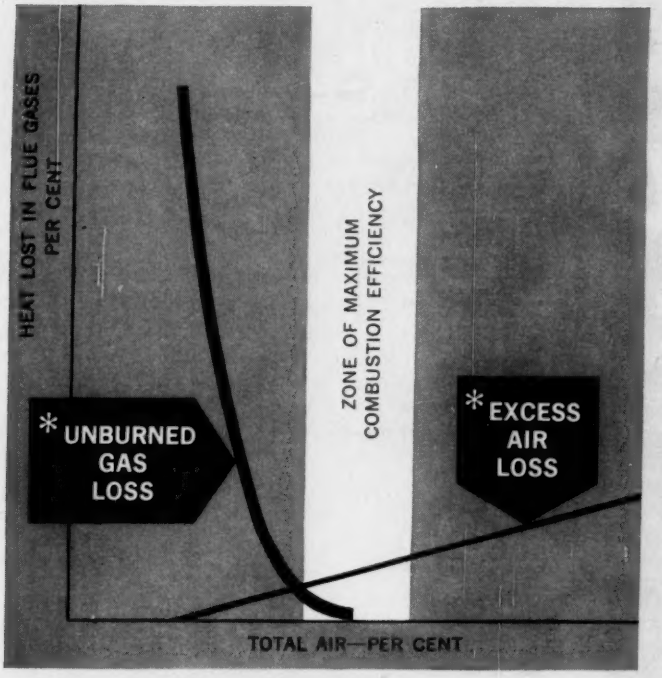
Eldorado Electronics

2821 TENTH STREET
BERKELEY 10, CALIFORNIA
PHONE: THORNWALL 1-4613

21

CIRCLE 19 ON READER-SERVICE CARD

You must know BOTH* to get maximum combustion efficiency!

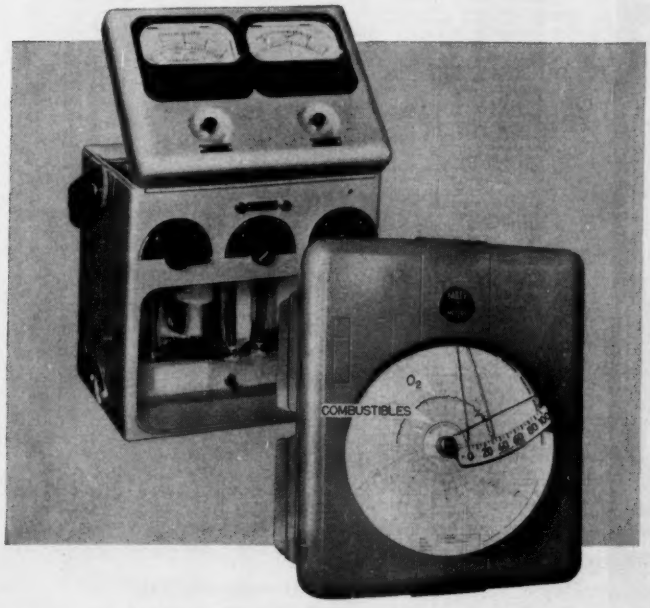

HEAT LOST IN FLUE GASES PER CENT
ZONE OF MAXIMUM COMBUSTION EFFICIENCY
* UNBURNED GAS LOSS
* EXCESS AIR LOSS
TOTAL AIR—PER CENT

How much money is going up the flue in *unburned fuel* losses? Is too much air resulting in excessive *heat* losses?

You must know *both* facts—simultaneously—to get optimum combustion. No instrument that measures only one of these interdependent factors can give you the full information you need.

Bailey offers a choice of two direct ways to maintain a continuous and simultaneous double check on these factors that determine combustion efficiency. The portable, lightweight Bailey HEAT PROVER Analyzer indicates both; the Bailey Oxygen-Combustibles Analyzer-Recorder records both on a single chart. Both instruments measure excess air, regardless of fuel or fuels being burned, and per cent of combustibles in flue gas.

Either of these Bailey instruments can save you far more than their cost in spotlighting combustion inefficiencies. Ask your Bailey engineer or write for product specifications.



2 DIRECT WAYS
to measure both combustibles and oxygen simultaneously

PORTABLE INDICATOR—Self-contained, lightweight, Bailey HEAT PROVER Analyzer enables quick, easy check on combustion conditions. Dual range dials for greater accuracy and readability.

PERMANENT RECORDER—Bailey Oxygen-Combustibles Analyzer-Recorder coordinates both records on one chart . . . is designed for permanent installation . . . helps maintain optimum ratio continuously.

* Unburned gas loss and excess air loss.

G 155-1

Instruments and controls for power and process

BAILEY METER COMPANY

1041 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

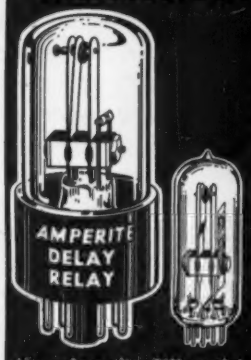
CIRCLE 20 ON READER-SERVICE CARD

Large production gives you low prices!
– that's why . . .

Over 100 O.E.Ms have standardized on

AMPERITE

Thermostatic DELAY RELAYS



2 to 180 Seconds

Actuated by a heater, they operate on A.C., D.C., or Pulsating Current.

Hermetically sealed. Not affected by altitude, moisture, or climate changes.

SPST only—normally open or closed.

Compensated for ambient temperature changes from —55° to +80° C. Heaters consume approximately 2 W. and may be operated continuously. The units are **rugged, explosion-proof, long-lived,** and—**inexpensive!**

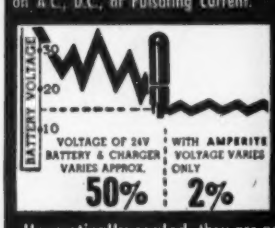
TYPES: Standard Radio Octal, and 9-Pin Miniature . . . **List Price, $4.00.**

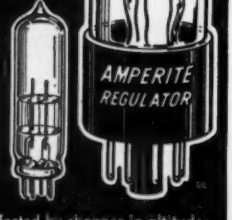
Also—**Amperite Differential Relays:** Used for automatic overload, under-voltage or under-current protection.

PROBLEM? Send for Bulletin No. TR-81

BALLAST REGULATORS

Amperite Regulators are designed to keep the current in a circuit **automatically regulated** at a definite value (for example, 0.5 amp.) . . . For currents of 60 ma. to 5 amps. Operate on A.C., D.C., or Pulsating Current.





Hermetically sealed, they are not affected by changes in altitude, ambient temperature (—50° to +70° C.), or humidity . . . Rugged, light, compact, most inexpensive . . . . . **List Price, $3.00.**

Write for 4-page Technical Bulletin No. AB-51

AMPERITE

561 Broadway, New York 12, N. Y. . . . CAnal 6-1446

In Canada: Atlas Radio Corp., Ltd., 50 Wingold Ave., Toronto 10

CIRCLE 21 ON READER-SERVICE CARD

IGS STOCK REPORT

Further information may be obtained from the Research Department, Bache & Co., 36 Wall Street, New York 5, N. Y.

NEW YORK STOCK EXCHANGE

PRICE RANGE FOR 1961 THRU MARCH 21, 1961

	High	Low	Price As Of 3/21/61
ACF Industries	55 1/4	38	55 1/4
Aeroquip Corp.	33 3/4	22 1/4	32
Allis Chalmers	27 7/8	23 3/8	26 1/2
American Chain & Cable	49 1/2	42 7/8	48 1/4
Amer. Mach. & Foundry	123 1/2	85 1/4	111 3/4
Amer. Mach. & Metals	44 3/4	34 1/8	42 1/4
American Meter	53	43	48 7/8
American Optical	65 1/2	54	62 1/8
American Tel. & Tel.	117	103 1/8	111 1/4
Ampex Corp.	25 3/8	20 1/4	23 1/8
Aro Equipment	31	20 1/4	27
Bausch & Lomb Optical	46 5/8	40 1/2	41 1/2
Beckman Instruments	139 3/4	87	139 3/4
Bell & Howell	63 1/4	48 3/4	60 1/2
Bendix Aviation	72	62 1/4	63 3/8
Boeing Airplane	47 5/8	35 1/2	46 5/8
Bullard	17 3/8	11 1/4	15 3/4
Bulova Watch	18 1/2	15 7/8	17 3/8
Burroughs	38 1/4	27 1/2	37 5/8
Carborundum	58 1/2	44 1/4	57 1/4
Cinn. Milling Machine	49 1/4	37 1/2	46 3/8
Clevite	64 7/8	47 3/4	63
Columbia Broadcasting Sys.	40 1/2	35 3/8	38 1/4
Consol. Electronics	46 1/2	38 5/8	41 3/4
Corning Glass	184 1/4	167	181
Curtiss Wright	22	15 5/8	19 7/8
Cutler-Hammer	74	62 3/8	66 3/4
Daystrom	34 3/4	28 1/2	29 7/8
Douglas Aircraft	38 1/2	28	35 7/8
Eastman Kodak	119 1/2	104 1/4	115
Eaton Mfg.	36 7/8	30 3/8	36 1/8
Electric Auto-Lite	55	44 5/8	55
Elgin Watch	14 3/4	11 3/4	14
Emerson Electric	81 3/4	50	75
Engelhard Industries	22 3/4	18 1/2	22 1/4
Food Mach. & Chem.	76 1/2	59 1/8	74 1/8
Garrett	56 3/8	48	55 1/2
General Controls	22 1/4	17 3/4	21 7/8
General Dynamics	45 1/2	39 3/8	39 7/8
General Electric	74	61 1/8	66 5/8
General Instruments	50 7/8	37 5/8	48 3/4
General Mills	37	31 3/8	33 1/8
Gen. Precision Equip.	75 5/8	54 1/2	70 3/4
Gen. Railway Signal	44 1/4	29	42 1/4
Gen. Tel. & Elect.	30	26 1/2	29 1/4
General Time	20 3/8	14 1/4	19 1/4
General Tire & Rubber	68 1/2	54	63 3/8
International Bus. Mach.	733	580	711
International Resistance	34 1/4	26	31 7/8
Intern'l. Tel. & Tel.	59 7/8	44 3/4	58 7/8
I-T-E Circuit Breaker	24 5/8	19 3/4	21 5/8
Lear Inc.	21 5/8	16	22 1/4
Litton Industries	128 1/2	87 1/8	122 3/4
Lockheed Aircraft	42 1/2	26 1/2	41 3/8
Magnavox	69 1/4	46	69 1/4
Mallory	45 1/4	36 5/8	43 1/2
Manning, Maxwell & Moore	26 1/2	21 7/8	25 3/4
Minneapolis-Honeywell	170 3/4	140	158
Minnesota Mining & Mfg.	84 1/2	70 1/8	82 1/2
Motorola	90 1/4	75 1/8	89 3/8
National Acme	59 1/2	47	55 1/2
National Cash Register	83 3/4	61 7/8	83 1/4
Neptune Meter	29 1/2	22 7/8	24 5/8
North American Aviation	53 5/8	45	49 1/8
Northrop Aircraft	52 7/8	41 1/2	50
Otis Elevator	76 1/4	56 1/2	75
Philco Corp.	22 7/8	17 3/4	22
Radio Corp. of Amer.	59 3/4	49 1/2	58 1/8
Raytheon Mfg.	41 1/8	35 1/4	36 5/8
Reliance Electric	57 1/2	47 1/2	56 3/4
Rheem Mfg.	18 1/4	13 1/2	16 1/4
Robertshaw Fulton	41 1/4	32 7/8	39
Royal McBee	16 5/8	13 1/4	16 1/8
Sangamo Electric	16 1/2	14 3/8	15 3/4
Siegler Corp.	32 3/4	27	32 3/4
Sperry Rand	29 1/4	21	28 1/4
Square D	37	29 5/8	35 1/8
Standard Kollsman	41 1/2	25 1/8	41 1/2
Starrett (L.S.)	22	17 3/4	21
Stewart-Warner	28 1/4	24 3/4	28
Telautograph	16 1/8	12 5/8	13 1/8
Texas Instruments	196	165 3/4	183 1/4
Thompson-Ramo-Wooldridge	82 3/8	67 3/4	79
Tung-Sol Electric	31 5/8	25 3/8	27 7/8
Underwood Corp.	54 7/8	42 1/2	52
Union Carbide Corp.	132 1/2	116	132
United Shoe Machinery	73	54 5/8	73
Varian Associates	64	46 5/8	61 3/8
Wallace & Tiernan (new) (a)	40	26 1/2	35 1/4
Western Union	54 1/8	39 3/4	53 3/8
Westinghouse Air Brake	26 3/8	22	25 1/8
Westinghouse Electric	50	40 5/8	44 1/4
Worthington Corp.	59 7/8	49	58 1/2

These prices and price ranges are given as printed in the Wall Street Journal.

AMERICAN STOCK EXCHANGE

PRICE RANGE 1961 THRU MARCH 21, 1961

	High	Low	Price As Of 3/21/61
Barry Wright Corp.	22 1/4	15	20 7/8
Belock Instruments	18 3/8	14 5/8	18 7/8
Benrus Watch	7 1/8	6	7 1/8
Breeze Corp.	6 3/4	4 1/8	6
Burnell & Co.	10 1/4	6 1/2	9
Clark Controller	19 5/8	16 1/2	19
Clarostat Mfg.	18 1/2	12	19 1/8
Clary Corp.	15 1/4	8 5/8	15 1/4

(*Continued from Page* 582)

Cubic Corp.	82 1/2	51 1/2	81 1/4
Dynamics Corp. of Amer.	11	7 5/8	10 5/8
El-Tronics	7 3/8	5	7 1/4
Electronics Corp. of Amer.	13 1/2	9	12 1/2
Fairchild Camera & Instruments	172	130	164 1/4
Fischer & Porter Co.	29 3/8	16	28 7/8
Giannini Controls	71 1/2	52	67
Globe Union	29 7/8	23 1/2	29
Hazeltine Corp.	35	25 1/2	34 1/4
Loral-Electronics (new) (a)	44 1/2	31 5/8	41 5/8
National Research	31 1/2	17 5/8	30
New Haven Clock	1 1/2	1 1/8	1 3/8
Nuclear Corp. of Amer.	5 3/8	3 7/8	4 3/4
Philips Electronics, Inc.	38 1/2	32 1/4	36 1/4
Pneumatic Scale	50	39 1/2	46 3/4
Polarad Electronics	25 5/8	18 3/4	25
Servo Corp. of Amer.	16 3/8	11 1/4	14 1/2
Servomechanisms	11	7 3/4	9 1/2
Statham Instruments Inc.	35 3/8	26	29 5/8
Textron Electronics	12 1/2	9 3/8	11 5/8
Victoreen Instrument Co.	18	13 1/8	15 1/8
Waltham Prec. Instr. Co.	2 5/8	1 3/4	2 3/8

These prices and price ranges are given as printed in the Wall Street Journal.

Barry Controls merged with Wright Line, Inc., new name is Barry Wright Corp.

OVER THE COUNTER

	Quotation As of March 21, 1961	
	Bid	Asked
Aerovox Corp.	8 1/2	9 1/2
Argus Corp.	39 1/8	39 5/8
Black Sivalls & Bryson Inc.	14 3/4	15 1/2
Computer Systems	17 1/2	18 1/2
Eitel Mc Cullough	19 7/8	20 3/8
Electro Instruments	31 1/2	33 1/2
Electronics Associates	37	38
Erie Resistor Corporation	13 1/2	14
Fisher Governor Co.	24	24 1/2
Foxboro Company (new)	74	76
Hagan Chemicals & Controls	51 1/2	53
Milgo Electronic Corp.	26	27
Industro Transitor	4 5/8	5 1/8
Liquidometer Corp.	18 1/2	19 1/4
W. L. Maxson	20 1/2	21
Hewlett-Packard Co.	36 5/8	37 1/8
Penn Controls	22 1/4	23 1/4
Speer Carbon, Inc.	22	22 3/4
Sprague Electric	62 1/2	63 1/2
Taylor Instruments (new)	46 1/2	48
Telechrome Mfg. Corp.	16 3/8	16 7/8
Telecomputing Corp.	7 1/2	7 3/4
Vitro Corp. of Amer.	22 3/4	23 1/4
Wallson Associates Inc.	5	5 1/2

CHARTS
for Recording Instruments
We offer to the Instrument Maker Charts for all methods of Recording: Pen, Ball Point, Electrical, Thermal, Pressure and Inks for Diazo and general use. Uniform accuracy is assured through the use of specialized equipment operated under controlled atmospheric humidity conditions.
GUBELMAN CHARTS
Div. of Nashua Corporation
100-6 E. KINNEY ST., NEWARK 5, N. J.

MODEL HA 150R
A 60 kV unit is also available.

CARL ZEISS

NEW High Voltage Supply Unit

with built-in electronic stabilizer. 150 *kV D.C.*

Made in West Germany

This new unit embodies the most advanced features and offers important advantages in research and technical fields. It can be used for: High voltage supply for electron-optical examinations . . . Examinations of structure by means of electron diffraction . . . Deflecting voltage for particle accelerators . . . High voltage source for neutron generators . . . Electric testing of materials . . . Electrostatic spraying . . . Electronic sorting . . . High voltage supply during lectures, etc.

A safety device is incorporated to protect the operator against being subjected to dangerous high-voltage discharges. The unit is free of disturbing high-frequency radiation, and has only small interfering magnetic fields. Line voltage fluctuations of ±10% have practically no influence upon output. Mounted on casters —easily movable.

Write for literature.

COMPLETE SERVICE FACILITIES

CARL ZEISS, INC.

485 FIFTH AVENUE, NEW YORK 17, N. Y.

CIRCLE 22 ON READER-SERVICE CARD

Moore Products introduces a new name

SOLID STATE PNEUMATICS

—for an entirely new instrument technology

Today, Moore engineers are working in applied research—with encouraging results—on the use of new operating principles which they call

SSP

For tomorrow, these principles are showing promise for a line of pneumatic process-control and computing instruments which will

—have no moving parts

—have extremely high speed response

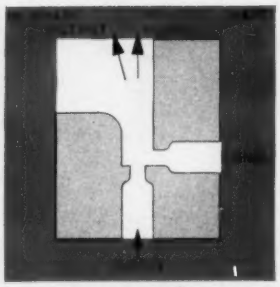
—receive and transmit shock wave signal

—be free of ambient-temperature limitations

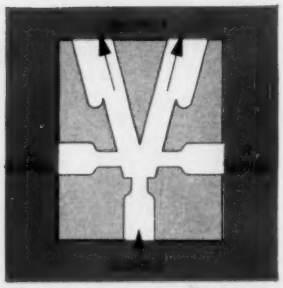
—operate at low or high power levels

—be unaffected by vibration or acceleration

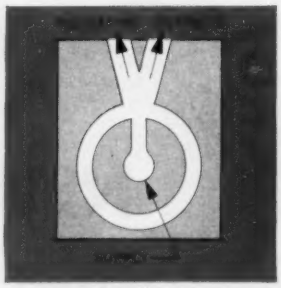
SSP **is still in the research and development stage. Here are schematic diagrams of a few of the current projects.**



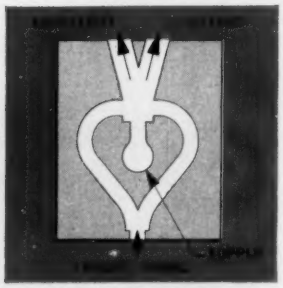
Basic Amplifier



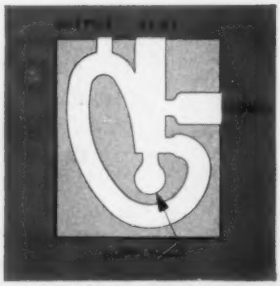
Binary Computer Element with memory



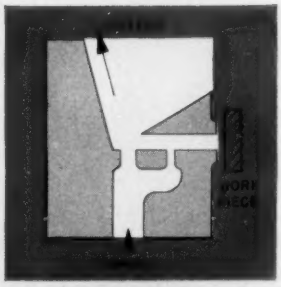
Oscillator



Pulse Counter



Holding-in Relay (positive feedback)



High-speed Dimensional Gaging Switch

MOORE PRODUCTS CO., PHILADELPHIA 24, PA.

Manufacturers of NULLMATIC Industrial Instruments and Moore Pneumatic Comparator Gages

Offices in Twenty-one Principal Cities of the U. S. and Canada

CIRCLE 23 ON READER-SERVICE CARD

CIRCLE 24 ON READER-SERVICE CARD→

How to make a shrewd increase in recorder efficiency

With twice the performance, the Ampex FR-600 is still compatible with earlier equipment.

Doubles tape utilization and obviates standby equipment

Your FR-600 records 125 kc data at 30 ips instead of 60 – gives twice the recording time per reel. For example, you get 48 minutes recording time on 10½-inch reels, 96 minutes on 14-inch at 30 ips. Not only are tape expenditures cut in half, but standby recorders on long sessions may no longer be needed. And for a broader data spectrum in the future, your FR-600 can accommodate 250 kc at 60 ips or 500 kc at 120 ips.

Multiplies available recording time and eliminates error

Two-hour warmup and adjust sessions are reduced to ten minutes by the FR-600's transistorized circuitry. Final calibration is a one-time-per-use operation. Post-warmup stability – less than 1% drift per 24 hours – precludes time-wasting adjustments and minimizes creeping inaccuracies. Because your FR-600 is ready when needed, it works more hours per day, saving both your time and its own.

Updates performance of older equipment

The FR-600 plays back tapes from most existing data recorders. And because playback heads generally determine overall frequency response, use of an FR-600 for playback can permit earlier equipment (with simple adjustment) to record the same high information density as your FR-600.

The essential data

The Model: FR-600 Laboratory Recorder/Reproducer. *Number of tracks:* up to 14. *Reel sizes and tape widths:* 10½- or 14-inch NAB, with ½-inch or 1-inch tape, interchangeably. *Frequency response:* 300 to 250,000 cps ± 3 db at 60 ips with direct recordings; 0 to 20,000 cps ± 0.25 db at 60 ips in FM-carrier recording — proportionate response at other speeds. *Tape speeds:* 60, 30, 15, 7½ ips; 120, 3¾, 1⅞ ips optional. *Types of recording:* direct, PDM and FM-carrier, by plug-in modules. *Compatibility:* yes, with Ampex 300 and 800 series; FR-100 and FR-1100 series, and AR-200 and CP-100 series.

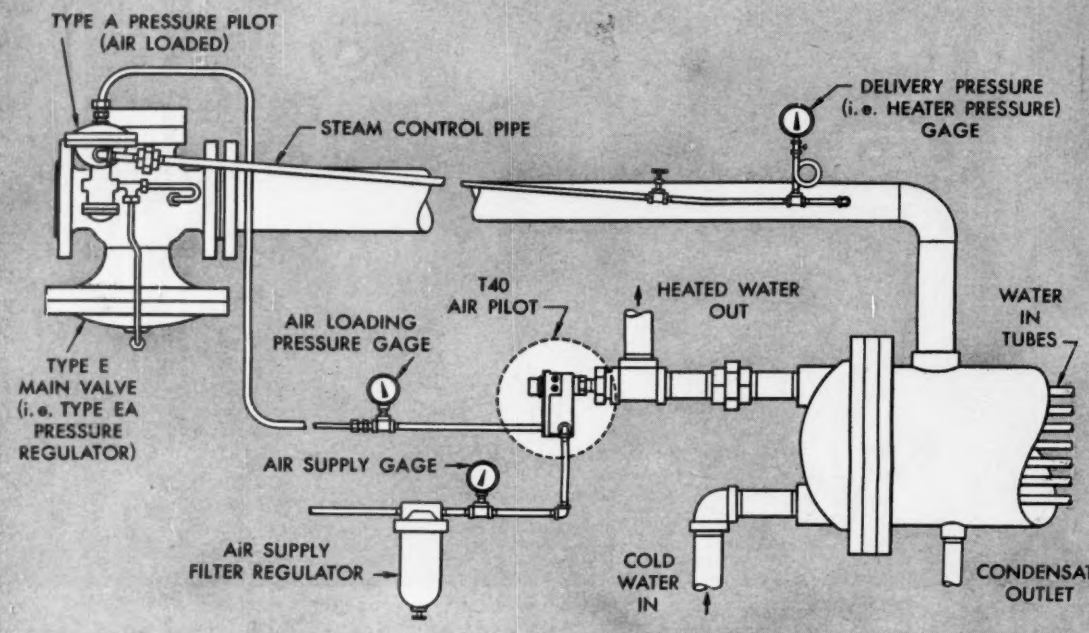
For detailed information on the complete Ampex line of data recorders, write:

AMPEX INSTRUMENTATION PRODUCTS COMPANY
Box 5000, Redwood City, California

AMPEX

Experienced engineers eager to contribute to Ampex's pioneering reputation are invited to write the Manager, Technical Recruiting.

New Spence Temperature Control System with Cascade Control Accuracy at Regulator Costs


TYPE A PRESSURE PILOT (AIR LOADED)
STEAM CONTROL PIPE
DELIVERY PRESSURE (i.e. HEATER PRESSURE) GAGE
T40 AIR PILOT
HEATED WATER OUT
WATER IN TUBES
AIR LOADING PRESSURE GAGE
TYPE E MAIN VALVE (i.e. TYPE EA PRESSURE REGULATOR)
AIR SUPPLY GAGE
AIR SUPPLY FILTER REGULATOR
COLD WATER IN
CONDENSATE OUTLET

TYPE EAT40 AIR-CONTROL TEMPERATURE REGULATOR (Patent Pending)

In a recent installation the new Spence air-control temperature regulating system provided:

- ±5°F control accuracy under wide and instantaneous load swings of 210 to 80 gallons per minute.
- Up to 50% reduction in cost as compared to instrument systems of similar accuracy.

This unique cascade-type control with throttling range adjustment independent of maximum heater pressure was developed to meet today's demand for greater control accuracy.

Additional features of the new Spence Temperature Control System include:

- 200°F wide adjustable temperature range
- Adjustable speed of steam pressure change
- Over and under temperature protection
- Pressure limit control
- Fast response
- Very low air consumption
- Field reversible for heating or cooling

The Spence Type EAT Air Control Temperature System, when properly installed, will tame wide ranging, fast changing loads of instantaneous heaters and modern heat exchangers. The cascade principle plus the use of an extremely fast responding bi-metal temperature sensing element reduce time lags and provide control stability.

Here's how the new Spence system operates:

Quick response is based on a bi-metal temperature sensing element.

Temperature pilot continuously regulates a loading air pressure.

This loading signal, when applied to a pressure regulator to reflect heater temperatures, causes it to adjust the main valve as changes in load require.

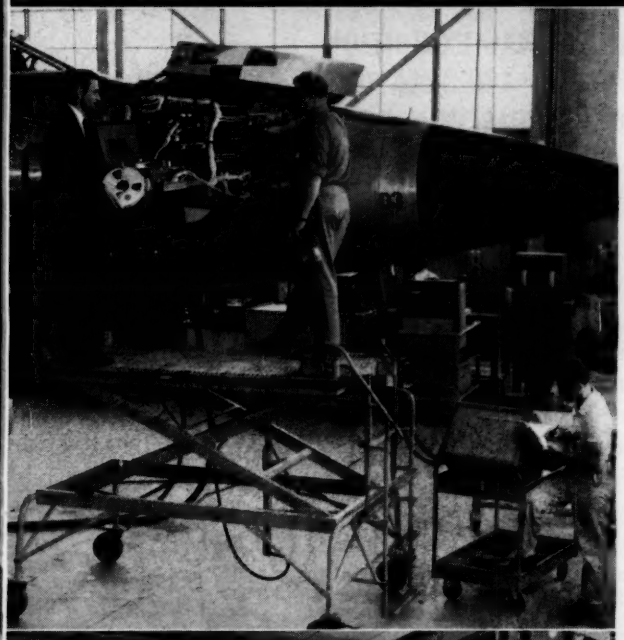
Spence has also developed a new pressure control system based on this same cascade principle. This system has a control accuracy of ½ psi or better from positive pressures through the vacuum range to 30" Hg.

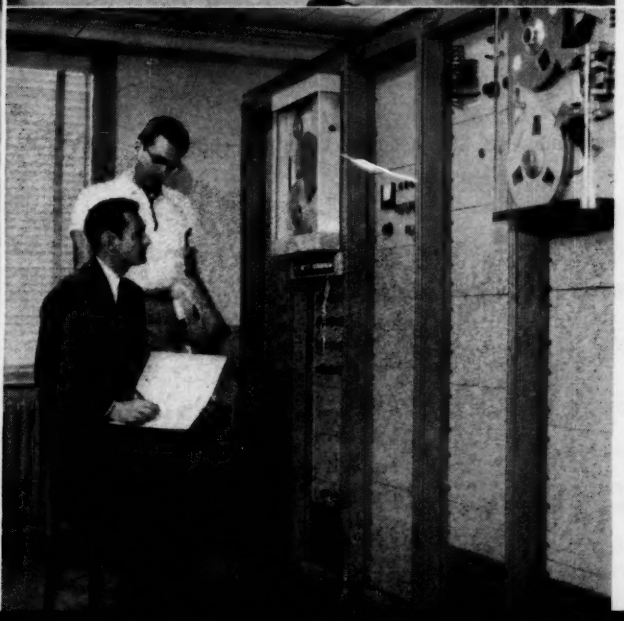
For complete information on these new air controlled temperature and pressure control systems, write for your copy of Bulletin 9.

SPENCE ENGINEERING COMPANY, INC.
Walden 1, New York
SE-148A

CIRCLE 25 ON READER-SERVICE CARD

IN WEAPONS SYSTEM EVALUATION
EPSCO DELIVERS ITS SPECIFICATION





Currently in use at EGLIN AFB...

ADVANCED AERO/SPACE DATA SYSTEM DOES 10 DAYS' WORK OVERNIGHT

Since early 1960, this Epsco PCM Data Gathering System has been in use by Republic Aviation Corporation in its flight test program of the new F-105D Thunderchief Mach 2 fighter-bomber.

The Epsco PCM Airborne System samples, multiplexes, and digitizes 84 high- and low-level analog channels, then records these plus 15 auxiliary 13-bit digital inputs on a magnetic tape handler in the test aircraft. When the plane returns to ground, the digital tape is played back on the Epsco PCM Ground Station and the test data efficiently stripped, edited, and recorded in computer format for direct entry into Republic's IBM 704 computer. Through this high-speed data reduction process, all flight test information, including a full computational analysis of the F-105D's toss-bomb computer, is available by the next morning. This overnight speed with which data is made available cuts weeks from Republic's flight test data analysis time, materially speeding up the entire F-105D test program.

Epsco's PCM equipment was selected to meet the exacting test requirements of the F-105D weapons system because of such advanced design features as random programming, adjustment-free operation, system expandability, and operational versatility as well as inherent extreme accuracy and fast sampling speeds.

The advanced PCM system, Model PCM-S-4010, also may be supplied with airborne telemetering capability. For further details, write for Bulletin AE-Aero PCM.

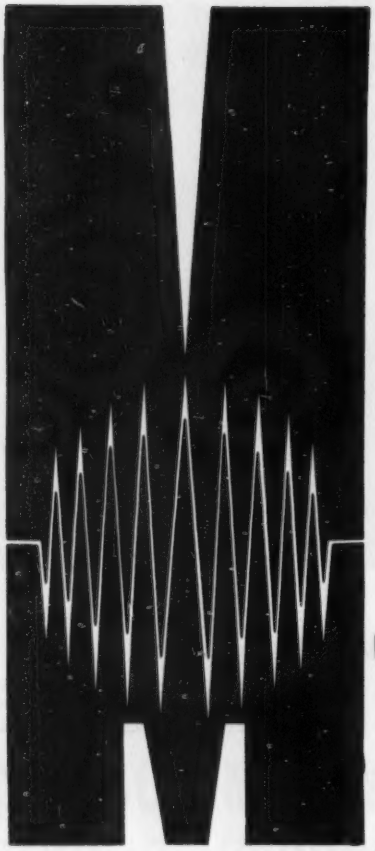
Upper left: Epsco PCM Airborne System in nose of F-105D test ship. Adjustment-free system permits prolonged operation without requiring access to installation.

Lower left: Epsco's PCM Ground Station features extensive search and editing functions to strip out desired data for analysis, prepares data for direct entry into Republic's IBM-704 Computer.

Epsco SYSTEMS

A Division of EPSCO, Incorporated
275 Massachusetts Ave., Cambridge 39, Mass. UNiversity 4-4950

CIRCLE 26 ON READER-SERVICE CARD



PARIS FROM MAY 9TH TO MAY 17TH 1961

MESUCORA

INTERNATIONAL EXHIBITION MEASUREMENT - CONTROL - REGULATION - AUTOMATION AND 58TH EXHIBITION OF THE "SOCIÉTÉ FRANÇAISE DE PHYSIQUE"

- First French Exhibition exclusively devoted to these techniques, the most important and the most international one realized in Europe.
- International Congress, the subject of which will be "Recent progress in the fields of Measurement, Control and automatic Regulation, resulting from the co-operation of the Techniques (electric, electronic, mechanical)".
- 700 Exhibitors - 14 nations - 35.000 square meters.
- The most recent discoveries and appliances of the theoretic and experimental research.
- Most refined measurement and control equipments, materials and methods; their applications to regulation and automation in the fields of the industry and of the public services.
- An unprecedented gathering, an international confrontation of the highest technical value which

ALL the responsible persons in industry and the public services
ALL engineers and research workers
ALL teachers and students of the technical and scientific Upper Teaching

MUST VISIT

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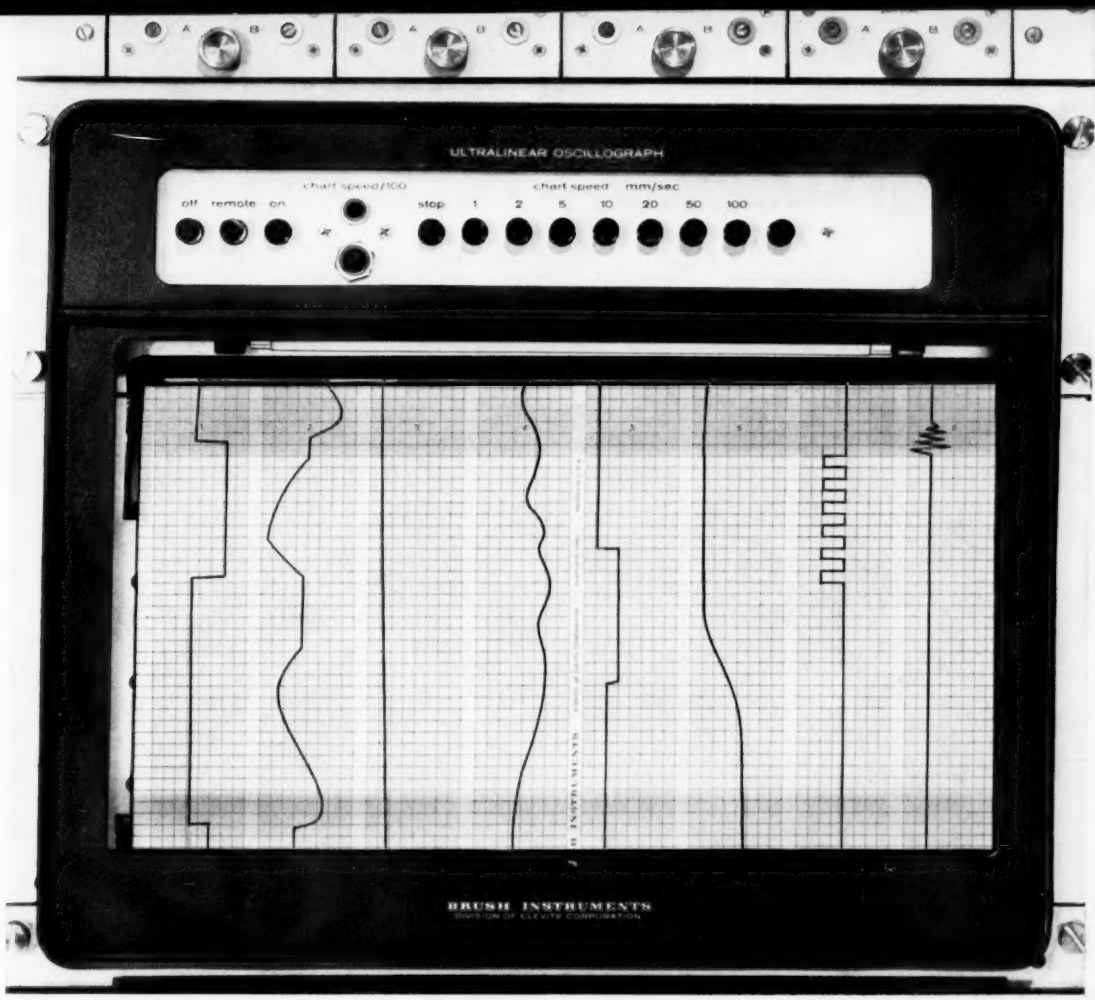
centre national des industries et des techniques

Call on : MESUCORA - Service Propagande - 40, rue du Colisée - Paris 8e - Tél. BALZAC 77-50
FRANCE for the complete documentation, stating if you want it in French, German or English.

CIRCLE 27 ON READER-SERVICE CARD

CIRCLE 28 ON READER-SERVICE CARD ⟶



in multi-channel recording systems there is nothing newer

. . . There are many reasons why Brush's newest oscillograph is the ideal choice for today's most advanced telemetry and computer systems. Its precision and reliability are proven. You get analog data instantly recorded on eight 40mm channels . . . and the sharpest traces on rectilinear coordinates you've ever seen. Thirteen electrically controlled chart speeds take the guesswork out of interpretation. *All* functions are operated by pushbutton . . . including an ingenious auto-load chart changing arrangement. But . . . the most important reason of all is that this vertical panel oscillograph carries the name "Brush". No one is as qualified. See for yourself. Call, write or wire.

brush INSTRUMENTS
DIVISION OF
CLEVITE CORPORATION
3700 PERKINS CLEVELAND 14, OHIO

MORE VALUE / LESS COST

CC108R

Versatility of the Conoflow LB valve makes it suitable for any control service—easy or tough. Write for literature today or contact your local Conoflow representative (in all principal cities) for prices.

CONOFLOW
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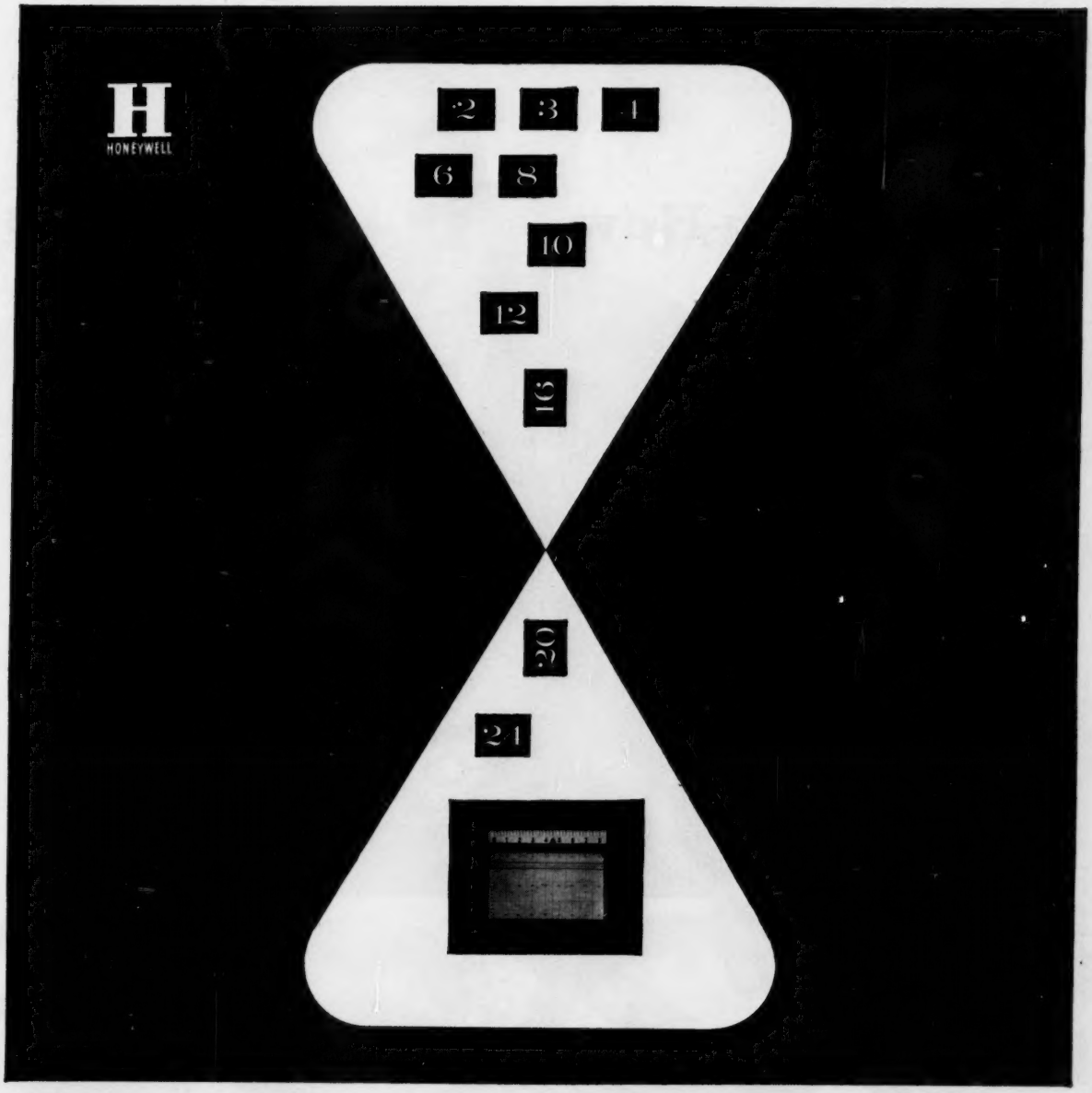
WALWORTH

CONOFLOW CORPORATION

FOREMOST IN FINAL CONTROL ELEMENTS

2100 ARCH STREET, PHILADELPHIA 3, PA.

CIRCLE 29 ON READER-SERVICE CARD



RECORD 2 TO 24 POINTS with ten-in-one "quick-change" instrument

With the new Universal Multipoint ElectroniK 15 Recorder on the job, you'll be able to change the number of recording points from 2 to 3, 4, 6, 8, 10, 12, 16, 20, or 24 in a matter of seconds. With this "quick-change" feature built into it, the new Universal can do the job of 10 recorders!

Conversion is as easy as this—remove thumb nut and slip off old print wheel and indicator dial, slip on new wheel and dial, replace nut, plug in number of points desired and you're ready to go!

If the monitoring jobs in your laboratory, industrial shop, or industrial process require frequent changes in the number of records required, you'll want to get the complete story on the new Universal Multipoint ElectroniK 15 Recorder.

Contact your nearby Honeywell field engineer for full details. Minneapolis-Honeywell, Wayne and Windrim Aves., Phila. 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell

First in Control

SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

CIRCLE 30 ON READER-SERVICE CARD

FLOW MEASUREMENT

Know-How makes the

DALL FLOW TUBES
Standard Models

Extremely low head loss reduces pumping and transmission costs. For mainline metering of water, sewage, non-corrosive trade wastes and gas, and low pressure steam. Available in 6" to 48" line sizes, pressures up to 250 psi. Durable, accurate, easily installed, low cost!

DALL FLOW TUBES
Plastic Insert Models

Corrosion-resistant construction . . . meters water, trade wastes, process chemicals, salt water, air and gases. Low cost, light weight, short laying length, high accuracy, low head loss!

DALL FLOW TUBES
Weldment Models

For specialized fluid measurement . . . metering petroleum, chemicals, gases or other process fluids at low or high pressures and temperatures. Strong weldments of wide variety of metals in many forms.

CIRCLE 31 ON READER-SERVICE CARD

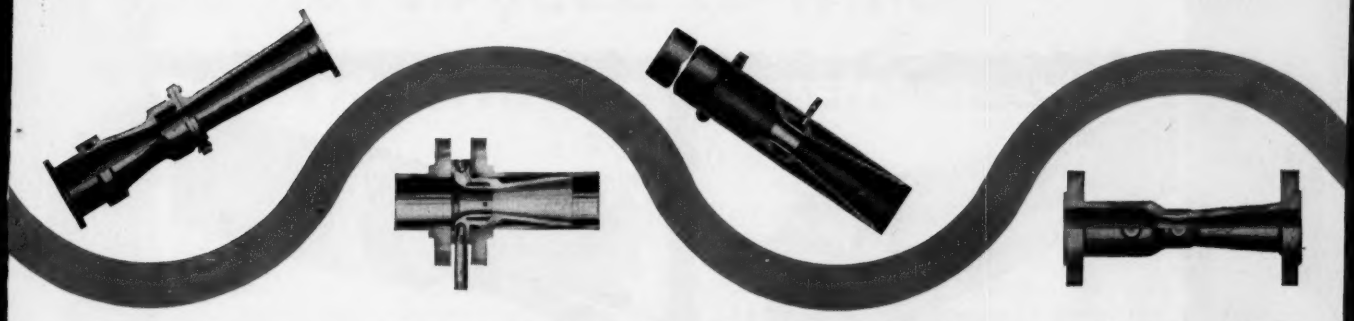
POSITIVE CONTROL OF MATERIALS IN MOTION B·I·F METERS FEEDERS CONTROLS

difference in differential producers

No single differential producer is "best" for all metering applications. Many factors influence the selection of the right primary element . . . type of fluid, desired accuracy, recovery requirement, capacity, upstream disturbances, etc. The difference between "average" and "best" metering of flows depends on a thorough evaluation of all pertinent factors.

B-I-F can give you better service on flow measurement than anyone else. We have done more of it . . . know more about it . . . and have the most complete line of differential producers. Unbiased recommendations are based on the most comprehensive, performance-proved flow application data available to industry. From B-I-F, you get "customized" metering to your exact application requirements at standard unit costs.

For fast, competent help, ensuring maximum efficiency from your instrumentation systems through proper primary selection, contact B-I-F. Request Ref. No. 100-P5-A for full details. Write **B-I-F Industries, Inc., 396 Harris Avenue, Providence 1, R. I.**



VENTURI TUBES

For mainline metering, pump testing, engine testing, high accuracy test installations . . . water, sewage, air and other fluids. Feature high accuracy, low head loss, constant discharge coefficient over wide flow range.

VENTURI INSERT NOZZLES, Flanged

For pump discharge, air conditioning condenser and chilled water loops, air to aircraft engines (production test work), and similar installations requiring high enduring accuracy. Insert design withstands severe thermal shock . . . pressures limited only by main pipe line.

VENTURI FLOW NOZZLES, Welded

Accepted standard for metering radioactive water in primary loops of atomic reactors, petroleum products in pipe lines, condensate lines, etc. Special tubes and nozzles suit all high pressure, high temperature or particular materials requirements.

SPECIAL VENTURI NOZZLES

Specifically designed for metering of sludges, slurries and liquids containing a high degree of settleable solids. Line sizes from 1" to 12". Cast iron or cast steel body with bronze or stainless steel trim. Single tap design adaptable to flushing and purging accessories.

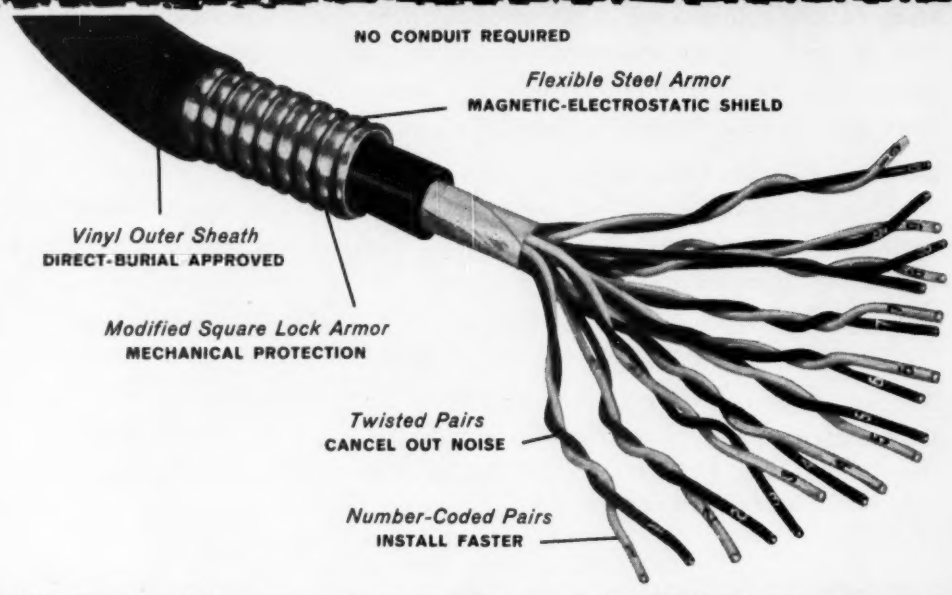
B·I·F Industries

BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA

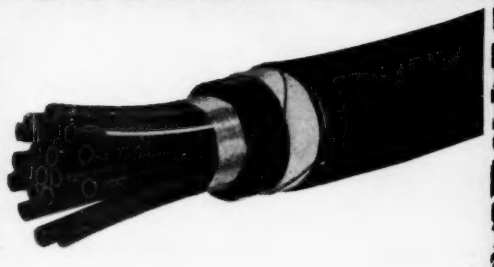
METERS • FEEDERS • CONTROLS / CONTINUOUS PROCESS ENGINEERING

DEKORON TYPE "AT" MULTICOUPLE EXTENSION WIRE WITH MAGNETIC SHIELD *keeps your process up to par years longer.*

Other advantages of Dekoron Type AT include easier installation . . . greater resistance to crushing, chemical and moisture attack for lowest maintenance. Always specify Dekoron products for maximum performance with minimized cost.



Dekoron New Metl-Cor combines exclusive parallel tubes of copper or aluminum with polyethylene protective sheath. Lack of "corkscrew effect" speeds installation. Dekoron also offers a full line of metal-armored tubing harnesses.



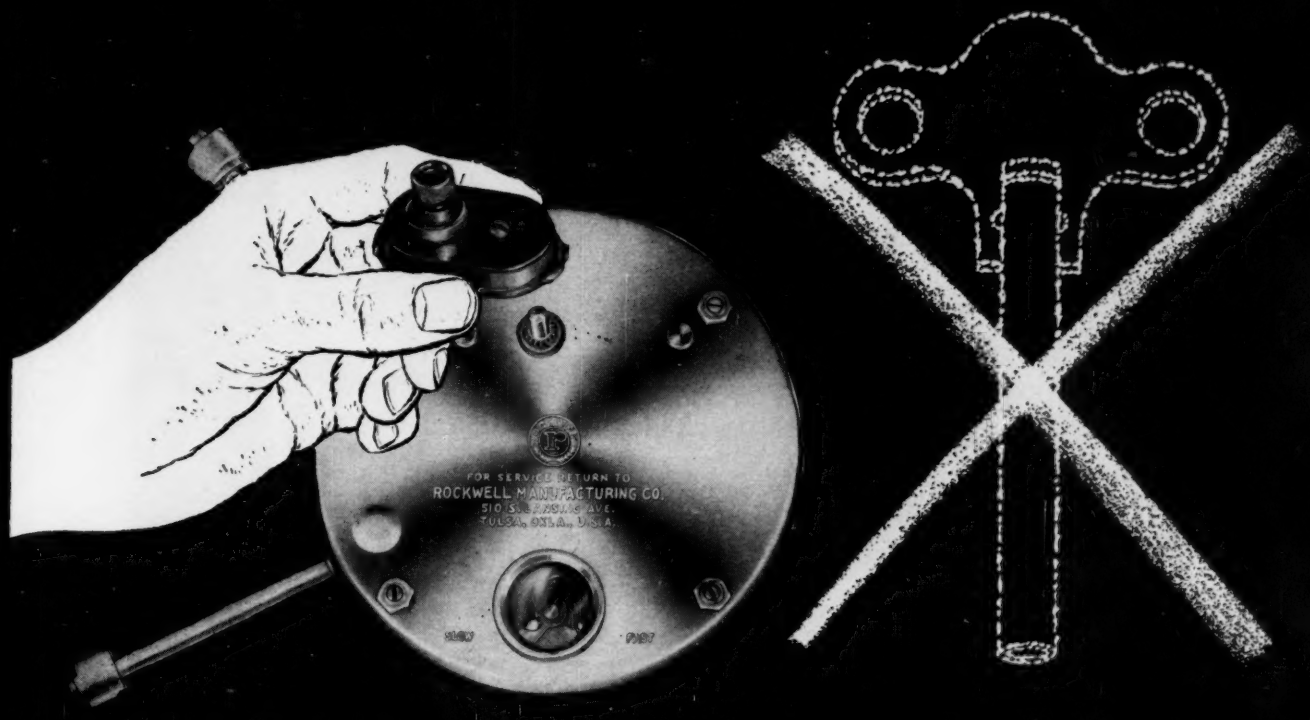
Dekoron Protecto-Pac (Type FB shown), an all-plastic harness with high resistance to weld splash, sparks, flash fires, etc. Dekoron Poly-Cor (not shown) has number-coded polyethylene tubes, Mylar® vapor barrier, flexible vinyl outer sheath.

Dekoron® products

quality • research • service

A-429-A

SAMUEL MOORE & COMPANY • DEKORON PRODUCTS DIVISION • MANTUA, OHIO



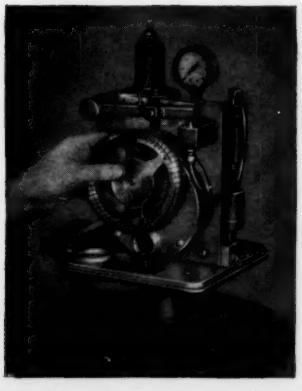
Illustrating how speed changing turrets are applied to the chart arbor

You never need to wind the Rockwell Gas Drive

GAS (OR AIR) POWERS THIS NEW CHART TIMING DRIVE. With it you can forget the costly chore of periodic winding. It's completely self-starting, self-contained. You can use the Rockwell Gas Drive with profit and gain accurate, automatic operation of recording charts on practically any make orifice meter, gas lift intermitter, pressure recorder or temperature gauge. It is particularly applicable for remotely located instruments.

Since the Rockwell Gas Drive consumes only 6 cubic feet of gas in 24 hours it is economical to use—safe, too, for there is no exhaust problem.

The Gas Drive operates on a pressure range of 15-25 psi and delivers 15 in. lbs. of torque to the main arbor which rotates once every 24 hours. Geared turrets which snap onto this arbor provide optional speeds of 2, 3, 4, 6, 12, 48 or 72 hour, 7 or 8 day rotation. So with a stock of Rockwell Gas Drives, plus a selection of economical turrets, you can serve all your instrument needs. Get facts now. Write Rockwell Manufacturing Company, Pittsburgh 8, Pa. In Canada: Rockwell Manufacturing Company of Canada, Ltd., Guelph, Ontario.



◀ Rockwell Gas Drive powers this typical intermitter

GAS DRIVES, CHART DRIVES

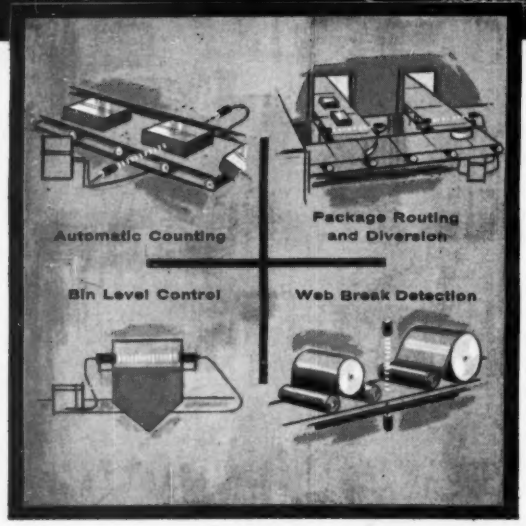
another fine product by

ROCKWELL

CIRCLE 33 ON READER-SERVICE CARD

←—CIRCLE 32 ON READER-SERVICE CARD

a new dimension in automated controls



SONAC ULTRASONIC,

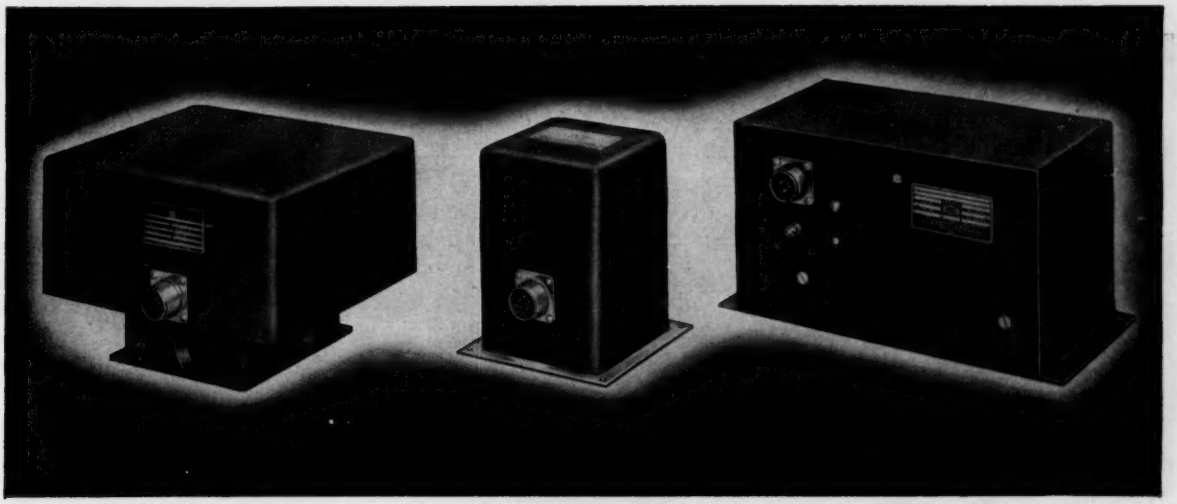
NON-CONTACT SENSING AND SWITCHING SYSTEM

Before Sonac, sensing and switching control systems which involved breaking a beam of energy were limited by vibration, dust, smoke, steam, air contamination and too much or too little light. Sonac's ultrasonic energy "beam" is completely free of these limitations. The acoustic lens on Sonac sensors can actually be painted without affecting performance. Utilizing high frequency sound also means there are no lamps to burn out. Savings in replacement parts and maintenance time often means Sonac pays for itself. Sonac is completely transistorized, providing you with a rugged, dependable electronic circuit.

These are just a few of Sonac's many uses. Optional equipment includes reflectors for precision beam and positioning control, and coupler assemblies for use with flexible tubing for remote sensor locations. This descriptive booklet will be sent to you on request.

DELAVAN Manufacturing Company
WEST DES MOINES • IOWA

CIRCLE 34 ON READER-SERVICE CARD



Where can you use solid-state inverters with performance like this?

- **Wide operating temperature ranges**—Models now available and in development, designed for ambients ranging from a low of −55°C to +125°C.
- **Closer frequency regulation**—As close as ±0.02 cps under full load at ambients from +60°F to 175°F in some models.
- **Voltage regulation to ±0.87%** under full load at ambients ranging from −20°F to +175°F.
- **High-power-conversion efficiencies** under full load 28v dc input.
- **Protection against output overloads**—100 va models will withstand 100 va overloading, for 10 minute periods once an hour.
- **Transient voltage suppression**—Transient suppressor removes or attenuates voltage spikes—safeguards semi-conductor elements.

The inverters listed here are only a small portion of the Hamilton Standard line of power conversion equipment. Other models are available to satisfy a wide range of industrial power supply problems . . . microwave and telemetry systems . . . remote signalling, warning, and measurement systems—wherever circuit interruption cannot be tolerated.

Whatever your power conversion requirements are, Hamilton Standard engineering can be of real help to you now . . . in the initial planning or redesign stage.

CHARACTERISTICS OF 100-VA STATIC INVERTERS

CATALOG NO.	ECB-1.1-AA	ECB-1.1.7-AA	ECB-1.1.13-AA
Output			
Voltage	115v±1v	115v±5%	115v±5v
Frequency	400±¼ cps	400 cps±1%	400±1%
Phases	Three	Three	Single
Transient protection	Yes	Yes	Yes
Input voltage			
Nominal	28v dc	28v dc	28v dc
Range	18-29v dc	20-29v dc	18-29v dc
Dimensions	5"x6"x8¾"	5"x6"x7⅝"	5⅛"x5⅛"x8⅜"

SEND FOR YOUR COPY of this illustrated Static Power Conversion Guide. Clip coupon and mail to:

STATIC INVERTER GUIDE

HAMILTON STANDARD • Electronics Department
Section 110, Broad Brook, Connecticut

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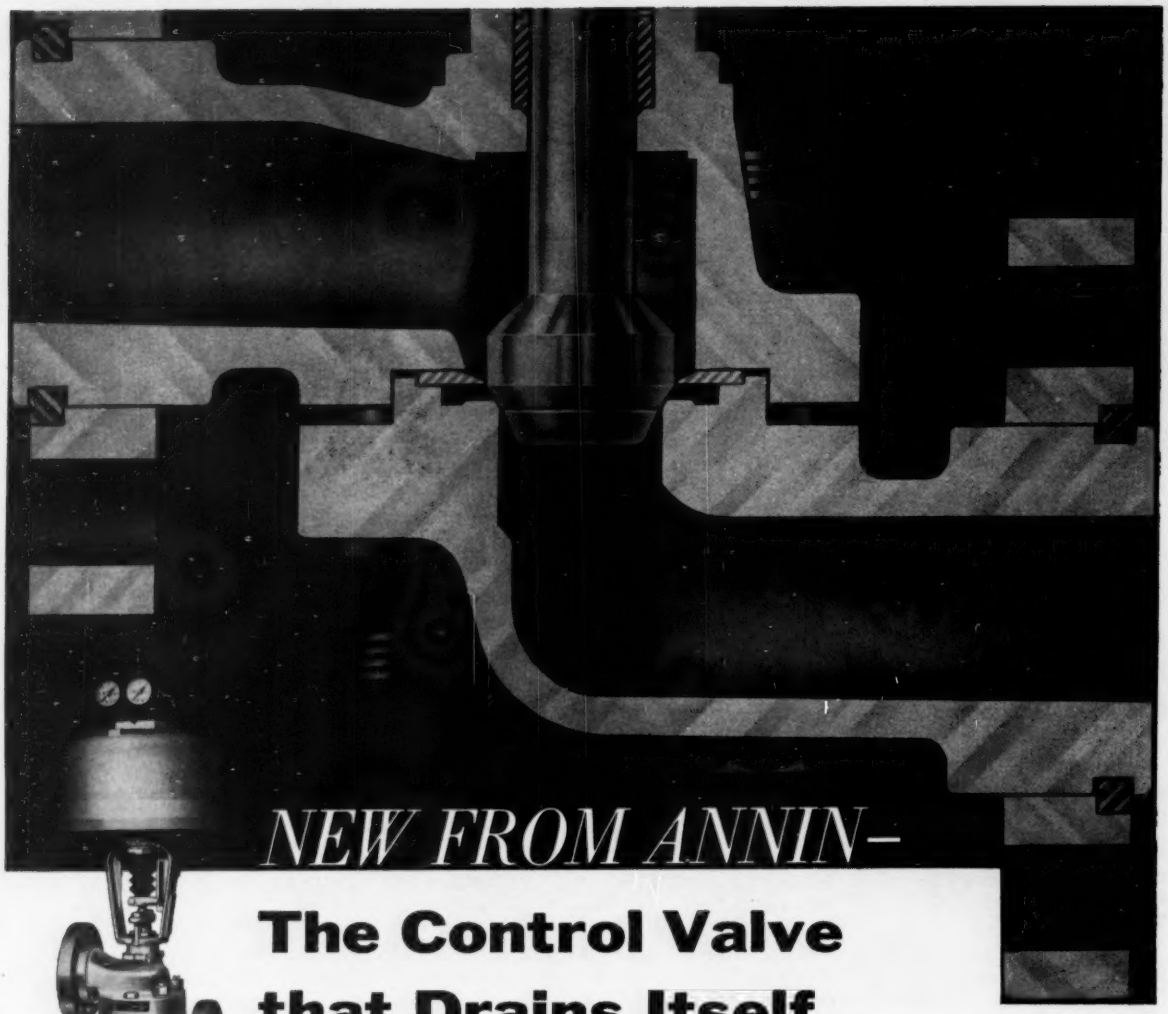
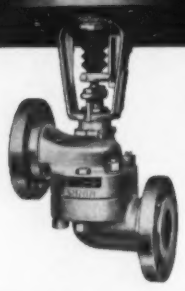
ELECTRONICS

CIRCLE 37 ON READER-SERVICE CARD



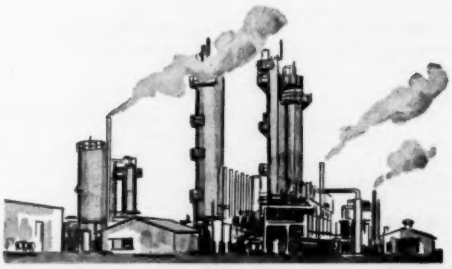
NEW FROM ANNIN–

The Control Valve that Drains Itself



ANNIN'S MODEL 1900 SELF-DRAINING CONTROL VALVE is designed to completely drain the line and valve body of corrosive fluids, slurries, and other flowing media which contaminate or tend to set up and harden in the system. Body and trim are designed so that all surfaces slope downstream, making the valve completely self-draining when installed in either the horizontal or vertical position. All body parts are interchangeable with other Annin models, allowing an option of globe, angle or three-way body patterns. Model 1900 is designed to accept all standard actuators—Pneumatic Domotor, Electro-Pneumatic, Electro-Hydraulic, Cylinder or Manual.

Send for latest technical information.



Model 1900 has many applications in the process industries, both in batch operations which require cleansing of the system after each run and in continuous processes after the system is shut down. Unique self-draining design of the valve body eliminates problems of fluid contamination, fermentation, toxicity and solidification.

Annin **VALVES**

THE ANNIN COMPANY
1040 South Vail Avenue,
Montebello, California

CIRCLE 36 ON READER-SERVICE CARD

Teletype Model 28 ASR—
page printer, tape reader, tape punch . . .
all in one!

A compact data communications center

The Teletype Model 28 ASR set is a machine of many talents—time and money saving talents that are ready to go to work in your data and message communications systems.

The page printer provides facilities for sending and receiving on message paper or sprocket-fed forms. It can also be used for preparing records or as a read-out device. Platens are available to accommodate a variety of form widths, from 3⅝″ to 9″.

The punched tape equipment is unusually flexible and versatile. Facilities are provided for encoding data into tape (with or without printing on the tape) . . . transmitting from tape . . . integrating repetitive data from previously prepared tape with variable data by keyboard . . . obtaining punched tape as a by-product of communications for computer and other business machine input. There is a choice of four different punches and four different readers and, where additional tape punch facilities are needed, a model is also available with an auxiliary tape punch.

In addition, the Model 28 ASR comes equipped with a "big plus"—the Stunt Box, a built-in programming mechanism that offers an inexpensive solution to a wide variety of remote control and switching tasks, such as automatic station selection and telemetering.

All of these facilities are available to you in a compact console measuring approximately 39″ high, 36″ wide and 23″ deep.

Teletype Corporation manufactures this equipment for the Bell System and others who require the utmost reliability from their data communications facilities. Teletype equipment can be used with Data-Phone and other communications services.

For a free brochure on the Model 28 ASR, write to Teletype Corporation, Dept. 22D, 5555 Touhy Avenue, Skokie, Illinois.

TELETYPE®
CORPORATION • SUBSIDIARY OF *Western Electric Company* INC.

CIRCLE 35 ON READER-SERVICE CARD

The lineup, left to right—Diaphragm actuator, globe body . . . Cylinder actuator, split body . . . Diaphragm actuator, split body . . . Cylinder actuator, globe body.

Interchangeable!

MIX THEM, MATCH THEM TO THE JOB . . . AND SAVE!

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

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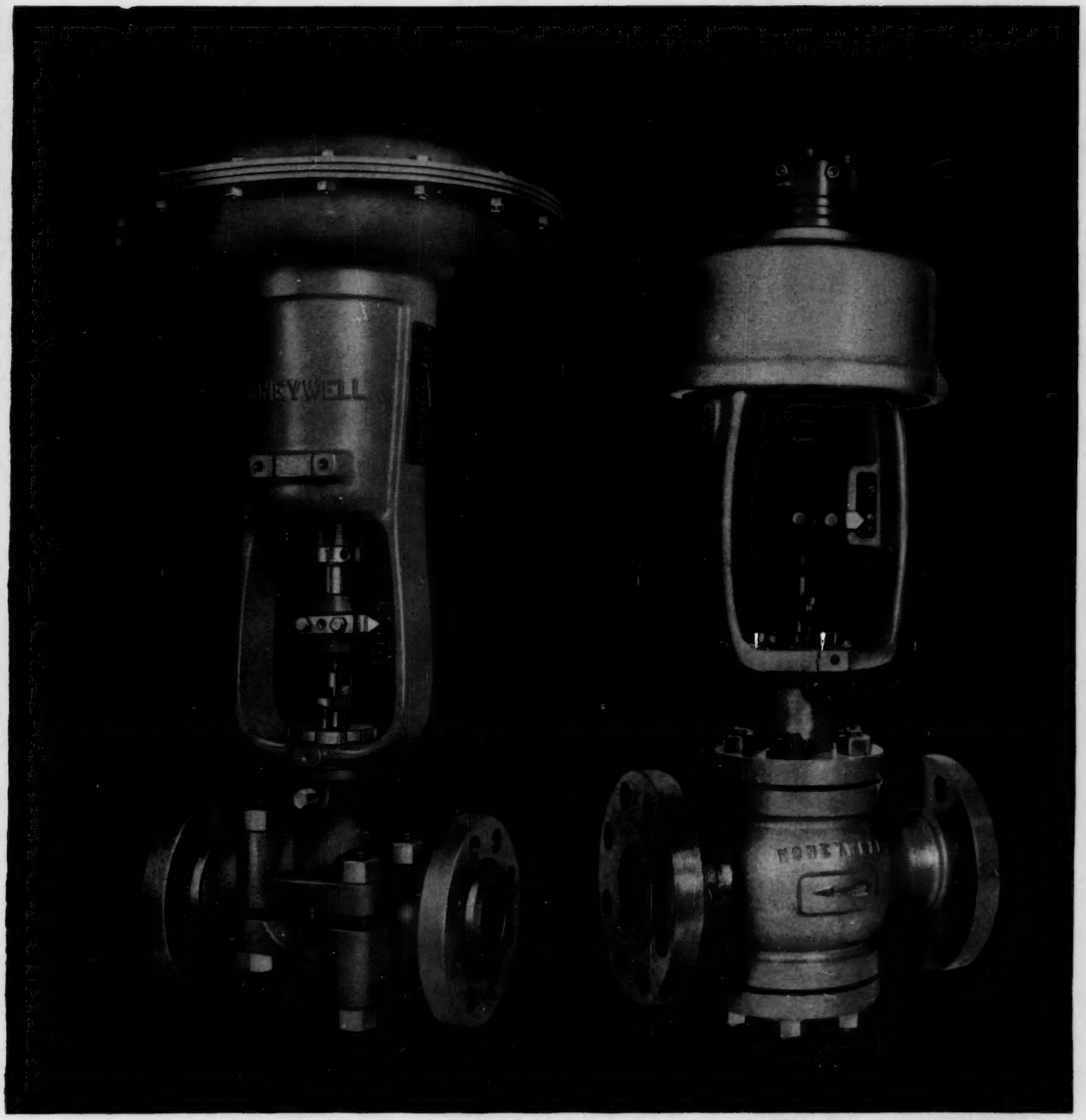
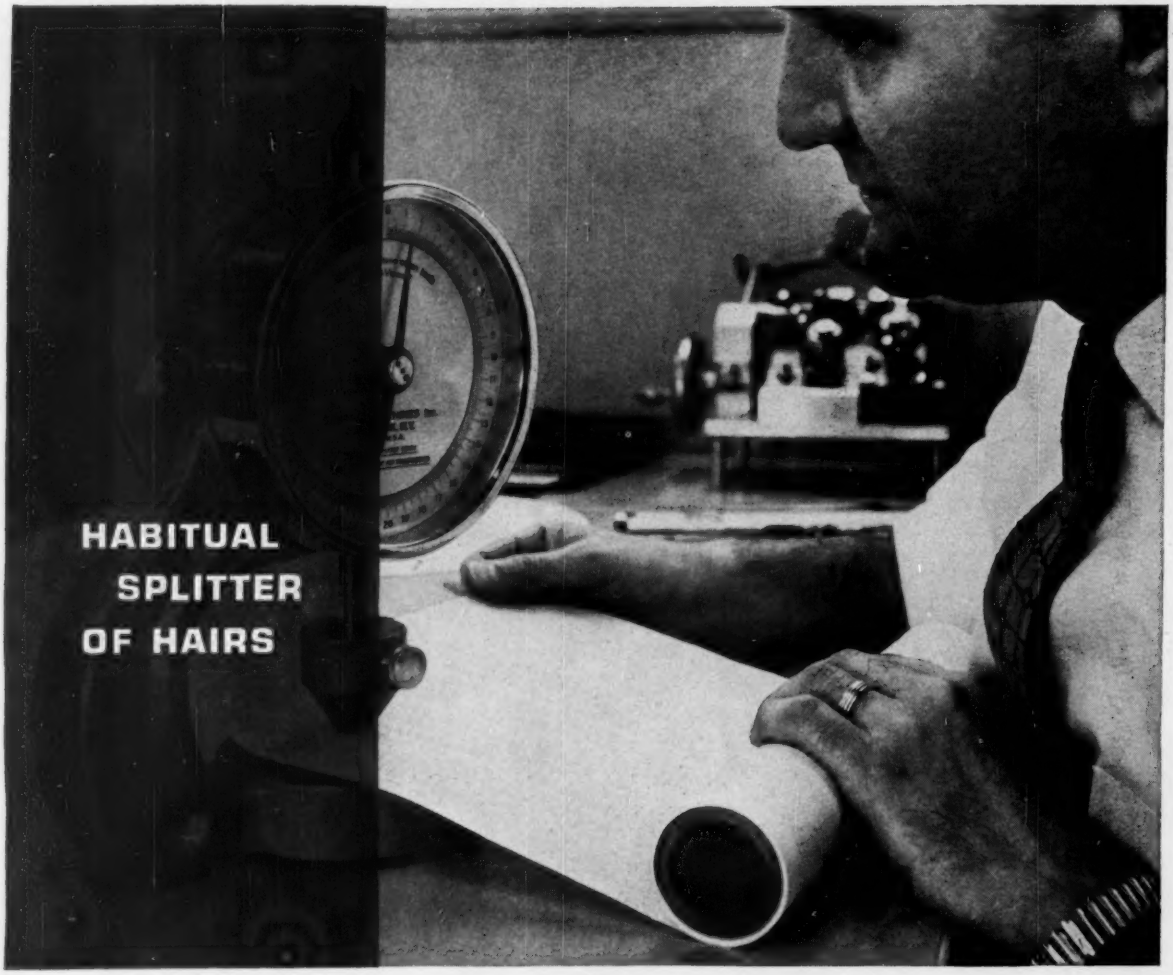


Honeywell's split-body and globe-body control valves team up beautifully with Honeywell cylinder and diaphragm type actuators. Use either actuator with either valve. The beauty lies both in the economy and perfect matching to the application made possible by this interchangeability. The "mix and match" versatility of Honeywell valves and actuators lets you select the exact degree of performance you require. No need to push a valve beyond its design limits, on one hand, or to pay for more performance than you need, on the other. You get the best valve-actuator combination for a given application, at the lowest cost. The new Honeywell "Valve Size Computer" helps you make your *mix and match* selection . . . send for yours today. MINNEAPOLIS-HONEYWELL, Fort Washington, Pa.

Honeywell

First in Control

SINCE 1885



. . . because a mil can matter greatly in RECORDING CHART PERFORMANCE

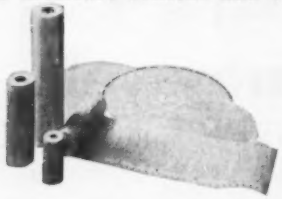
Even a fraction of a mil can bulk large in the thickness of a recording chart. That's why John Mazurowski and his thickness micrometer are so important to chart users.

A process change in an eastern oil refinery, for example, called for a longer strip chart in a temperature recorder — but the diameter of the roll could be no bigger than before. GC engineers solved this problem by working with our paper mills to reduce chart paper thickness from 0.00275" to 0.0019" while preserving strength and flexibility.

To make sure our charts meet the requirements of your instruments, GC engineers test paper stock for moisture content and tear-strength, too. This rigid inspection of paper that is produced exactly to GC specifications is a major reason why GC Recording Charts consistently fulfill their promise of accurate performance.

Other reasons for GC quality include our special formula printing inks, our exclusive innovations in plate-making and printing, and the scrupulous humidity control maintained throughout our manufacturing and storage areas.

GC Recording Charts have become standard equipment in more than 5,000 plants today. We stock more than 15,000 different charts — and will design and produce accurate special-purpose charts. Send for our newest Stock List — and for sample charts.



RECORDING CHARTS

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ICS BOOKS

Advances in Astronautical Sciences, Vol. 5, [c1960] American Astronautical Society, Inc. distributed by Plenum Press, Inc., 227 West 17th St., New York 11, N. Y., 356 pp., 10″, clothbound, $8.00. Volume represents Proceedings of the second Western National Meeting of the American Astronautical Society. Contains 26 reports on theoretical and experimental aspects of the most recent astronautical research.

Introduction to Laplace Transforms for Radio and Electronic Engineers, by W. D. Day [c1960], Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N. Y. 183 pp., 8½″, clothbound, $5.50. "Written by a radio engineer for radio engineers" this book uses practical approach of use of mathematics to solve practical problems. Gives the student the facility of using transforms to investigate transient conditions. Transforms will be found much easier to handle than differential equations.

Digital Computer and Control Engineering, by Robert Steven Ledley, [c1960] McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, N. Y., 835 pp., 9″, clothbound, $14.50. An elementary engineering textbook intended for senior undergraduates. Covers all aspects of the field from a detailed engineering point of view.

Digital Computer Principles, by Wayne C. Irwin, [c1960] D. Van Nostrand Company, Inc., 120 Alexander St., Princeton, N. J. 321 pp., 9″, clothbound, $8.00. A book for the beginner. Emphasis is on principles, illustrated with examples of circuits, devices, and systems. The author starts with the details and synthesizes a general system.

Semiconductor Digest, published by Systematic Programming & Editing Co., 3604 Woodland, Kansas City, Mo. 346 pp., 9″, ring-binder $12.50. Book consists of specifications on diodes, rectifiers, variable capacitors. Types of twenty-seven major manufacturers are listed. Electrical specs are arranged for immediate selection of type to solve specific application or replacement problems.

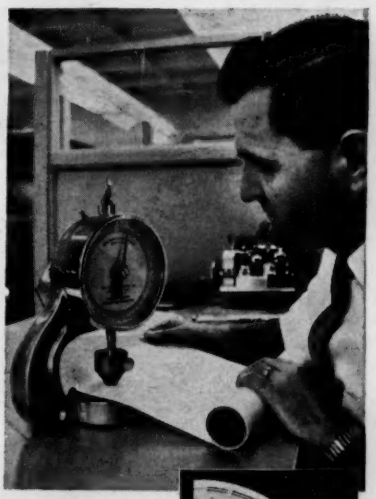
The Application of Elliptical Functions, by Alfred George Greenhill, Dover Publications, Inc., 180 Varick St., New York 14, N. Y., 357 pp, 8″, paperbound, $1.75. An unabridged, unaltered republication of the work first published in 1892. Formulas are developed immediately out of definite physical or geometric problems. Each problem is carried through step by step in detail.

Rocket Propellant Handbook, by Boris Kit and Douglas Evered, [c1960] The Macmillan Company 60 Fifth Ave., New York 11, N. Y., 354 pp., 9¼″, clothbound, $12.50. An unclassified reference work describing nearly a hundred chemicals for possible use as rocket propellants, including fuels, oxidizers, and monopropellants. Covers physical and chemical properties, performance characteristics, etc. and Contains valuable tabulated data for each substance.

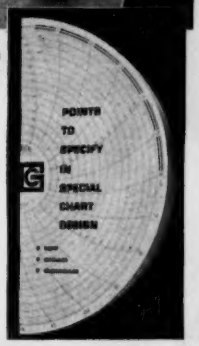
Basics of Induction Heating, by Chester A. Tudbury, in two volumes, [c1960] John F. Rider Publishers, Inc., 116 W. 14th St., New York 11, N. Y., 140 plus 144 pp., 9″, soft cover, $3.90 each. Intended for students in high schools, technical institutes, and industrial training courses. Explains what induction heating is and how it works. Uses "pictured text" approach. Has review questions at the end of each section.

Oersted and the Discovery of Electromagnetism, by Bern Dibner, [c1961] Burndy Library, Norwalk, Conn., 48 pp., 10¾″, paperbound $2.00. Monograph on milestones in the history of science in the Burndy collection of some 16,000 historic items describes Hans Christian Oersted's first experiment in 1820 which ranks next to Volta's original discovery of electric currents and Faraday's success in generating them from magnetism as one of the three great firsts that form the foundation of the age of electricity.

Pace TR-10 Transistorized Analog Computer Operator's Handbook, Electronic Associates, Inc., Long Branch, N. J., 70 pp., 11″, paperbound $1.75. Manual covers various computing components and their functions, introduces the reader to basic programming procedures and illustrates application of analog computation to a series of advanced problems.



GC Recording Charts are accurate



New booklet helps solve SPECIAL CHART problems

If you have a unique recording or control problem which a stock chart won't fit, GC's experience will work for you.

This free booklet, "Points to Specify in Special Chart Design," offers many useful tips to consider before specifying or designing a special chart. It suggests possible types of paper, sizing of punched holes, ink colors, overprinting, grid line widths, etc.

GC service—and this booklet—can eliminate false starts and wasted time. Let us serve you. Just send this coupon.

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Please send me your new folder "Points to Specify in Special Chart Design." No charge or obligation, of course.

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Firm_____
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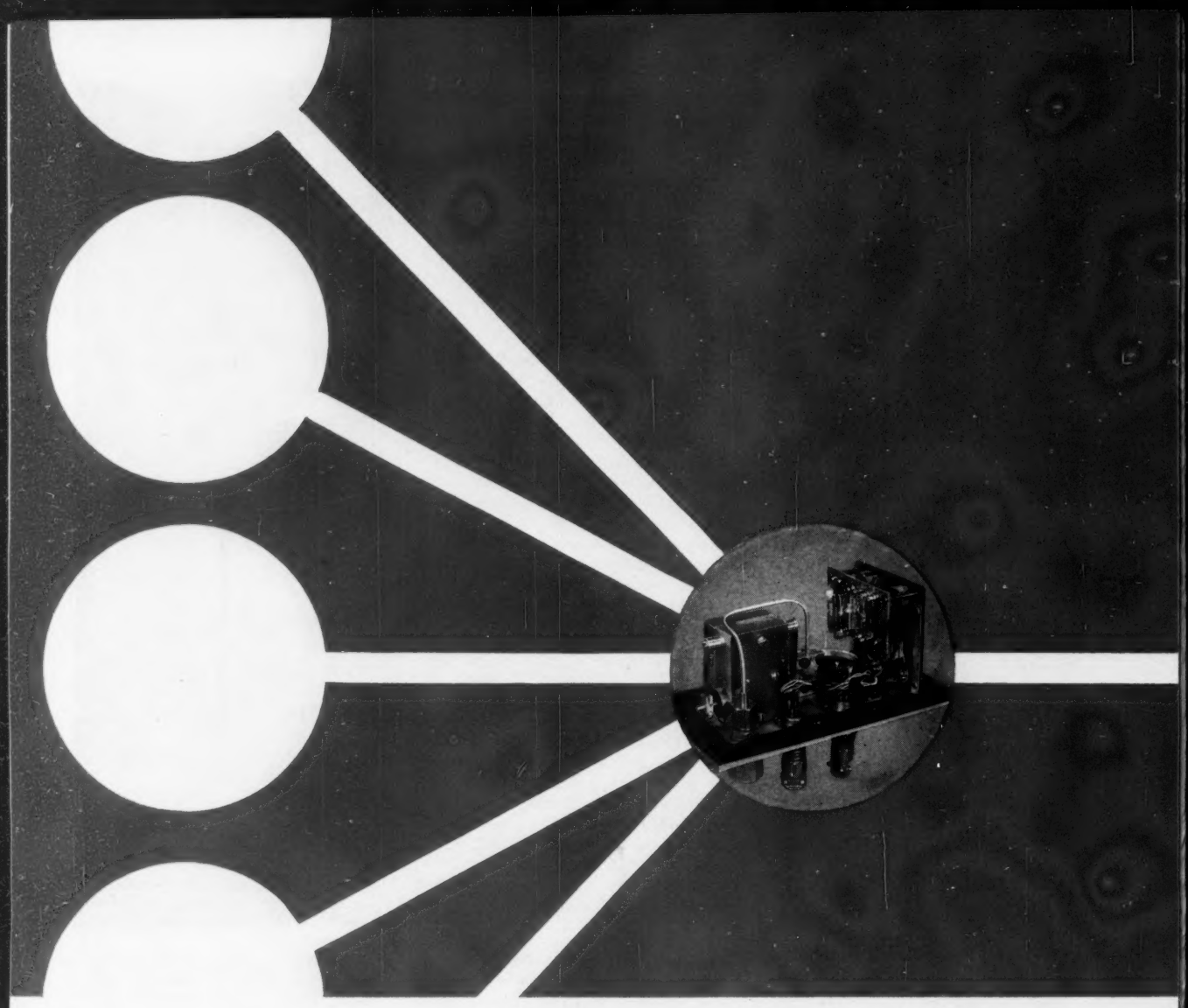

Take that first step accurately with

HAGAN PROCESS TRANSDUCERS

Whether you convert temperature, pressure or flow into a DC voltage, take this important initial step accurately. High accuracy transducers, using differential transformers (no slide wires), provide the critical "front end" for a process control system. Simple in design, and built to function in corrosive applications and hazardous locations, these instruments are rugged and reliable as well as accurate.

Here are typical Hagan PowrMag High Pressure Transducer (illustrated above with protective cover removed) specifications:

Input ranges—2 psig to 6000 psig
Linearity—± 0.5%
Temperature Coefficient—0.008%/°F
Resolution—0.001%
Output—1-9v DC, 0-8v DC
Dimensions—5½" x 8⅝" x 4⅝"
Repeatability—0.2%

Transducers are part of the complete PowrMag line, which includes all the components for complete control systems. All solid-state electronic, the system has been engineered to meet rigid specifications of performance, reliability and compatibility in original or replacement instrumentation applications. For more information, write or phone HAGAN CHEMICALS & CONTROLS, INC., Hagan Center, Pittsburgh 30, Pa. Telephone WAlnut 2-3737.

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HAGAN

Nash Instrument Air Compressors deliver only clean air, free from oil or dust, and without filters
INLET PORT
DISCHARGE PORT
DISCHARGE PORT
INLET PORT

Here is Why!

You can dispense with oil filters and dust filters when you install ®Nash® Clean Air Compressors. You can save the cost of maintaining these devices. You can greatly reduce instrument maintenance costs. For the Nash employs no internal lubrication, therefore no troublesome oil is in the delivered air. Moreover, air from a Nash is thoroughly washed and cooled as it passes thru the pump. Dust in the plant atmosphere, even fly ash, is immediately removed.

®Nash® Clean Air Compressors are simple, with only one moving element. No valves, gears, pistons, sliding vanes, or other enemies of long life and constant performance complicate a Nash. No aftercoolers are needed. You will find it profitable to investigate these pumps, now.

No oil filters.
No dust filters.
No internal lubrication to contaminate air handled.
No internal wearing parts.
No valves, pistons, or vanes.
Non-pulsating pressure.
Original performance constant over a long pump life.
Low maintenance cost.

NASH ENGINEERING COMPANY
370 WILSON, SO. NORWALK, CONN.

WORKING ON OUR second million

OVER 1,000,000
PANALARM
ANNUNCIATORS
are in process
industry
operations

More Panalarm Annunciators are specified and used because of:

Assured Reliability due to:

- 100% Inspection for all components, both in production and final assembly.
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Assured Reliability due to:

- Ultrasonic cleaning.
- No in-service gassing—moisture and destructive volatile materials eliminated by high vacuum oven baking.
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- Extra safety margin for Class 1 Division 2 applications provided by electronic halogen leak detection.
- After millions of operations, max. continuous contact pressure and uniform gap spacing are assured by beryllium copper contact springs.
- Hi temp cured TEFLON-covered coils.

Panalarm maintains a large staff of annunciator engineering specialists to assist with special annunciator design and application problems. Sales and engineering offices are in all principal cities.
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PANELLIT **DIVISION OF ISI INCORPORATED**

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Annunciators • Control Panels • Data Systems

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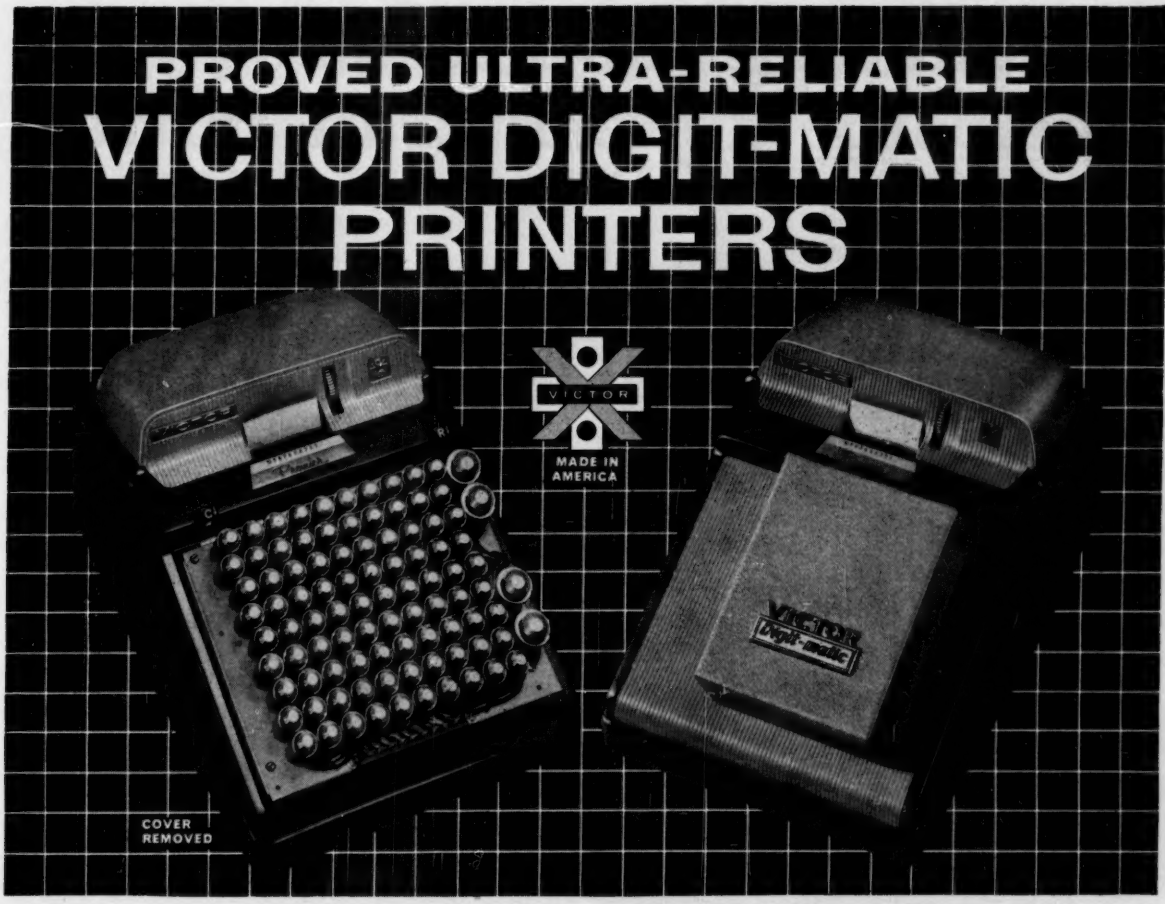
PROVED ULTRA-RELIABLE VICTOR DIGIT-MATIC PRINTERS



160,000,000 digit impressions without failure

Rugged, Trouble-Free—Digit-Matics are specially built to stand the strain of continuous operation. In a durability test, over 160 million digit impressions were made without breakdown or need of adjustment. The machine tested operated continuously, eight hours per day until 160 million digit impressions were made. During this period only normal lubrication and cleaning were performed.

Parallel or Serial Entry — Automatic and unattended, solenoid-activated Digit-Matics print out alpha-numeric data from remote equipment. High speed parallel entry models accept up to 10 digits at a time, print up to 4 lines per second. Serial entry models accept 1 digit at a time, up to 11 per line.

Two-Color Printing — Positive values in black, negative values in red. Ideal for "accept-reject" sequences, testing applications, accumulating data from two sources on one Digit-Matic, and many other uses.

Adaptable to Your Specific Needs — Line includes listers, accumulators and calculators. Versatile units can handle degrees, minutes, seconds, fractions. Other modifications: superimposed keyboard for manual use, time readings, counters, etc.

Immediate Field Service — 70 factory service branches and service representatives in over 600 cities assure uninterrupted operation. Victor offers 30-day delivery on most Digit-Matics. Mail coupon now for product data and application information.

VICTOR
ELECTRONICS DIVISION

Victor Adding Machine Co., Chicago 18, Illinois
Victor Adding Machine Co., (Canada) Ltd., Galt, Ont.

Manufacturers of Digit-Matic Printers, Scanning Printers, Electrical Keyboards, and Digit-Matic Data Punches

ICS-4

Victor Adding Machine Co.
Chicago 18, Illinois

Send full information on Victor Digit-Matics.

My application is_____

Name_____ Title_____

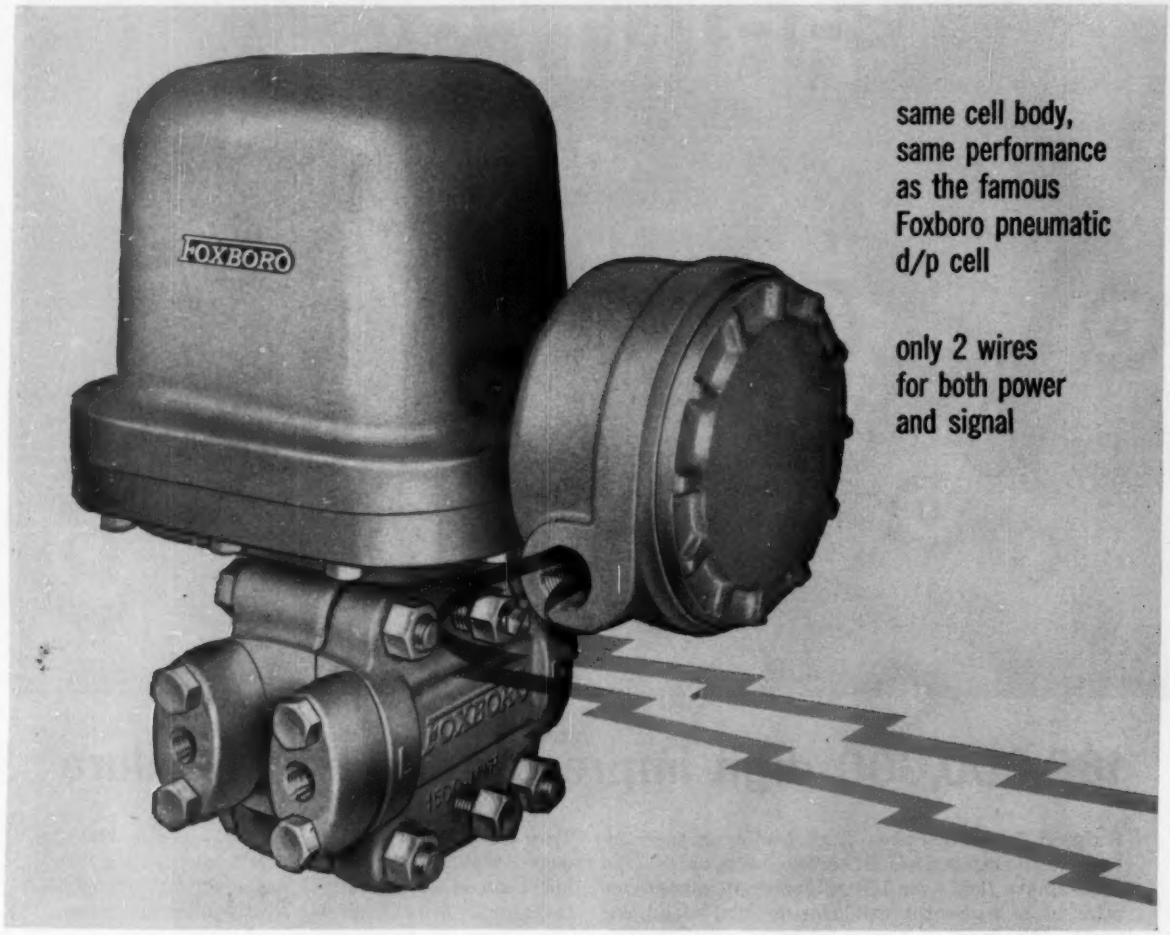
Company_____

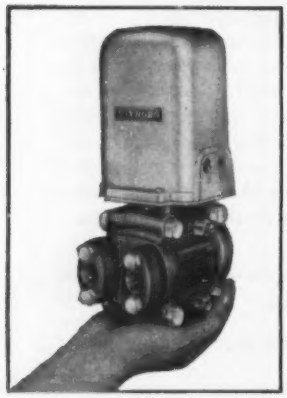
Address_____

City_____ State_____

CIRCLE 43 ON READER-SERVICE CARD

introducing the Foxboro electronic d/p cell* transmitter





The Foxboro electronic d/p cell transmitter and this Foxboro pneumatic d/p cell transmitter use the identical cell body. Only the top transmitting mechanism has been changed.

Yes, Foxboro has taken its famous pneumatic d/p Cell and added the benefits of electronic transmission. It's the new Foxboro *electronic* d/p Cell transmitter. Look at the results:

- both power and signal travel over the same pair of unshielded wires — no field power supply required
- pressure, flow, and level transmission up to several miles without lag
- true force-balance design for lowest displacement — highest overrange protection
- high level 10-50 ma d-c signal provides powerful rebalancing force
- adjustable ranges from 5" to 850" water with external zero adjustment — working pressures of 1500 and 6000 psi

And, of course, you get the same positive overrange protection, the same high sustained accuracy, the same rugged construction that has always been standard with the Foxboro d/p cell transmitter.

If you're thinking "electronic," it will pay you to investigate this important instrument in the Foxboro Electronic Consotrol* family. Get in touch with your Foxboro Field Engineer for complete details, or write for Bulletin 21-10. The Foxboro Company, 464 Neponset Avenue, Foxboro, Massachusetts.

**Reg. U.S. Pat. Off.*

FOXBORO
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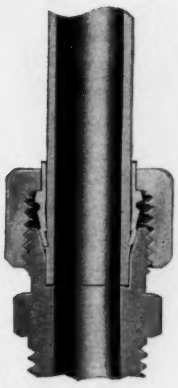
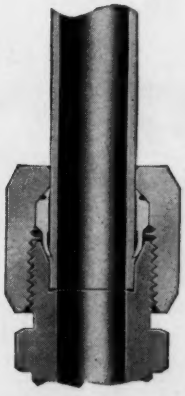
CIRCLE 44 ON READER-SERVICE CARD

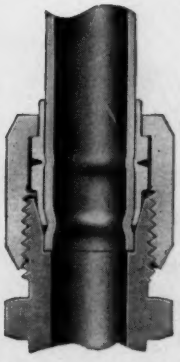
THESE PARKER TUBE FITTINGS MEET YOUR EXACT NEEDS



FOR INSTRUMENT AIR



FOR HIGH PRESSURES



COMPLETELY CORROSION RESISTANT

"INTRU-LOK®", the non-flare, "bite" fitting for copper, aluminum, Nylon or "Parker-POL" (polyethylene) tubing, features a "captive" ferrule you can't lose. It's simple, compact, easy to install, inexpensive. Available from stock in either brass or aluminum. Ask for catalog No. 4324.

"FERULOK®", the heavy-duty flareless fitting with the visible bite . . . you can see it, inspect it, make sure you have safe make-up. Usable with heavy-wall tubing for high pressure applications. Excellent vibration resistance. Made in steel, stainless steel, Monel. Ask for catalog No. 4320.

"RIDG-LOK", the all-stainless-steel (type 316) fitting for critical corrosion resistance applications. Unique ferrule design provides a safe, dependable, non-flare grip. Ferrule is "foolproof", with identical ends so there is no possibility of putting it in backwards. Ask for catalog No. 4322A.

Instrumentation and processing call for specific fittings—not a "general" type

It pays to be selective . . . to get the precise fitting for the job. Parker "Intru-lok®" is right for instrument air . . . small envelope, simple assembly, reasonable price. "Ferulok®" takes high pressures, assures safety from blowout. "Ridg-lok" is completely corrosion resistant.

No single fitting is right for every job. Parker fittings give you what you pay for – and what you need. *And there's a Parker fitting for every specific application.* For flared tubing, the Parker 37° "Triple-lok®" fitting is the leader.

For complete specifications and engineering help, check your nearest Parker distributor through the Yellow Pages, or write direct to:

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Parker FITTINGS AND HOSE DIVISION
17325 Euclid Avenue • Cleveland 12, Ohio
PNEUMATIC AND HYDRAULIC SYSTEM COMPONENTS
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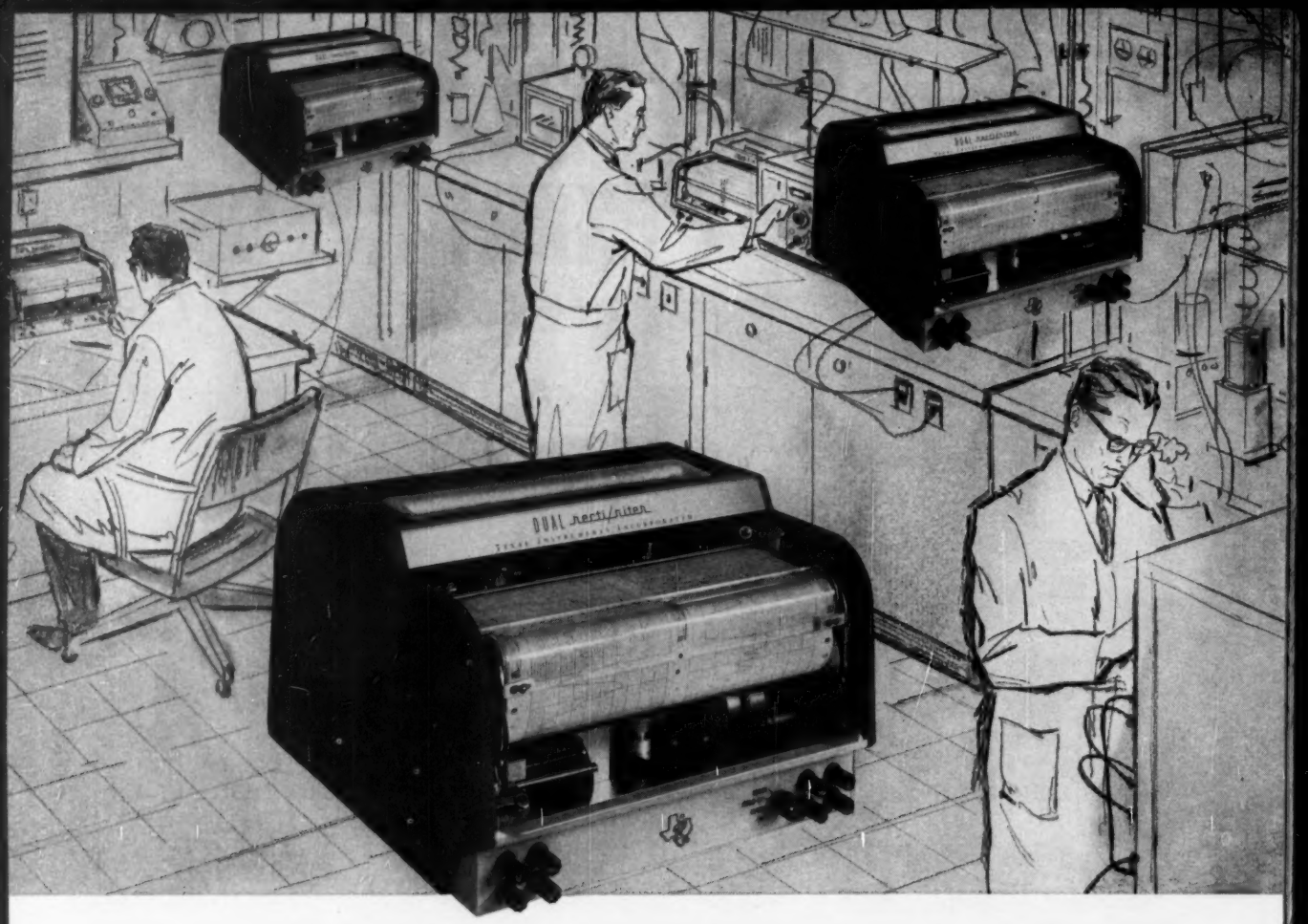
8171-PHa

CIRCLE 45 ON READER-SERVICE CARD



operator convenience makes the recti/riter® recorder preferred for laboratory use

The *recti/riter* recorder has become the *accepted* laboratory recorder—is preferred for the exacting tasks of laboratory applications. The portable *recti/riter* is the only galvanometric rectilinear recorder designed specifically as a bench-top instrument with all routine controls and adjustments located up front for extra convenience. The "writing desk" chart carriage permits operators to make the extensive notations usually associated with laboratory use while the instrument is recording.

Ruggedized die-cast construction results in an instrument that can "take it"—yet removal of the one-piece dust cover makes every working part completely accessible and removable without further disassembly. Every *recti/riter* carries a one-year full service warranty.

There is a *recti/riter* to fit your particular requirements—single and dual channel, portable and flush-mounting models . . . each available in the widest selection of standard ranges in the industry.

Two-Cycle Pen Response

d-c Milliampere Ranges	½ ma to 100 ma
a-c Ampere Ranges	0.25 amp to 25 amp
d-c Ampere Range	100 mv for use with standard shunts
Expanded Scale a-c Voltage Ranges	80-130 V, 160-260 V, 320-520 V
a-c and d-c Voltage Ranges	10 V to 1000 V
Frequency Ranges	50, 60, 400 cps

Five-Cycle Pen Response

d-c Milliampere Ranges	2.5 ma to 125 ma

Special options and accessories further expand the versatility of *recti/riter* recorders. Write now for complete information on this *accepted* laboratory recorder line.

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CIRCLE 46 ON READER-SERVICE CARD

PORTABLE PROTECTION

FOR *Precision* EQUIPMENT

Skydyne Molded Fiberglass hand-portable transit cases, with precision engineered interior cushioning and mounting hardware, provide maximum protection for delicate instruments and equipment.

HIGH RESISTANCE TO IMPACT, CHEMICALS, MOISTURE, CORROSION AND WEATHER.

HARD, MAR-RESISTANT, EASY-TO-CLEAN SURFACE.

MOLDED-IN COLORS. NO ADDITIONAL FINISHING REQUIRED.

LIGHT WEIGHT — GREATER STRENGTH, POUND FOR POUND, THAN OTHER MATERIALS.

IN-PLANT HANDLING CAUSES NO DENTING OR DISTORTION.

Available in 22 standard sizes, to meet MIL-T-945A and MIL-STD-108C specifications. Modifications provide a wide range of sizes for custom requirements.

Internal fittings can include brackets for mounting modular instrument panels.

INSTRUMENT CASE DESIGNED AND BUILT FOR LEAR, INC.

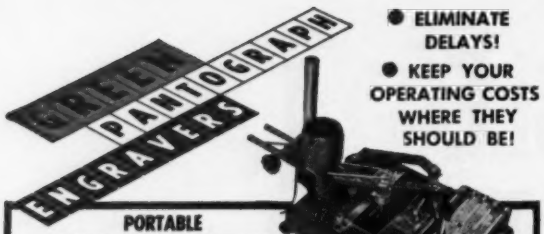
MINIMUM WEIGHT * Skydyne, Inc * MAXIMUM STRENGTH

Skydyne, Inc

RIVER ROAD PORT JERVIS, NEW YORK

SKYDYNE FIBERGLASS TRANSIT CASES—STANDARD CASES FOR CUSTOM EQUIPMENT.

CIRCLE 47 ON READER-SERVICE CARD



● ELIMINATE DELAYS!

● KEEP YOUR OPERATING COSTS WHERE THEY SHOULD BE!

PORTABLE
40-POUND BENCH MODEL 106

Here is a speedy, economical 2 or 3-dimensional engraver used by thousands of dollar-conscious companies. It features 5 positive, accurate pantographic ratios; ball bearing spindle with 3 speeds up to 14,000 rpm. Is supplied with one copy carrier that accepts all standard master type sizes. Will actually work up to 10" by any width. Height of pantograph and position of cutter are continuously adjustable.

You Make Your Own Engraved Nameplates!

MODEL D-2 HEAVY-DUTY 2-DIMENSIONAL
Pantograph for milling, drilling and engraving.

Vertical adjustment of copy table automatic with Pantograph. Features: unobstructed on 3 sides to take large work; micrometer adjustment for depth of cut; ball bearing construction throughout; spindle speeds up to 26,000 rpm for engraving or machining; vertical range over 10"; ratios 2 to 1 to infinity — master copy area 26" x 10"

NEW
MODEL D2-201 PNEUMATIC ATTACHMENT

for use with Model D2 Pantograph Engraver to rapidly drill holes in printed circuits by tracing templates. Drills as many as 100 holes per minute. Equipped with foot switch; spindle air cylinder; regulating valve and pressure gauge; filter and oiler. It's ready to use as soon as it's attached to an air compressor

Write or call for full details and prices.

GREEN INSTRUMENT COMPANY, INC.
Dept. 67 295 Vassar St.
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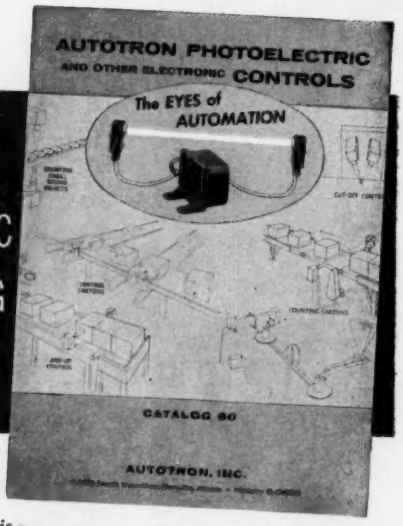
CIRCLE 48 ON READER-SERVICE CARD

NEW PHOTO-ELECTRIC CATALOG

Send for your copy TODAY



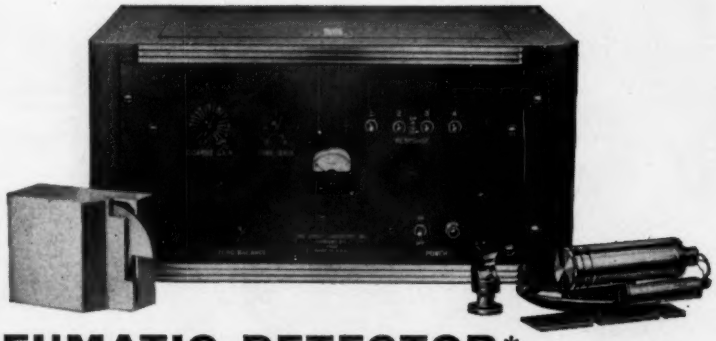
Describes transistorized and conventional photoelectric controls — normal, high speed, ultra sensitive and impulse actuated controls — photoelectric timing controls — complete line of light sources — including many protective features.

Simplified application diagrams cover widely varied requirements such as automatic control of conveyors; inspection, sorting, die protection, counting, weighing, limit control, car washing control, piling to exact count, safety control, conveyor traffic and jam-up control, timing control, spraying automation, automatic ramp traffic control.

AUTOTRON, INC.
Box 7229 Danville, Ill.
Representatives in principal cities

CIRCLE 49 ON READER-SERVICE CARD

A Superior Detector for Infra-Red Spectroscopy



GOLAY PNEUMATIC DETECTOR*

Among the characteristics that render the Golay Detector superior to other types of detectors for use in infra-red spectroscopy are:

1. **An effective sensitive area 3/32" in diameter.**
2. **Sensitivity of 6 x 10^{-11} watts RMS-ENI when used with "chopped beam" method and with recording time constant of 1.6 second.**
3. **Uniform sensitivity from the ultra-violet through the visible and the entire infra-red, and up to the microwave region.**
4. **Improved, drift-free. A. C. operated amplifier with step gain controls and four response periods.**

Write for EPLAB Bulletin No. 10

*Fundamental and experimental aspects of this detector are discussed in the following publications: Rev. Sci. Inst. *18*, 347 and 357 ('47); ibid. *20*, 816 ('49); Proc. IRE *40*, 1161 ('52).

278-S

THE EPPLEY LABORATORY, INC.
SCIENTIFIC INSTRUMENTS
2 Sheffield Ave. • Newport • Rhode Island • U.S.A.

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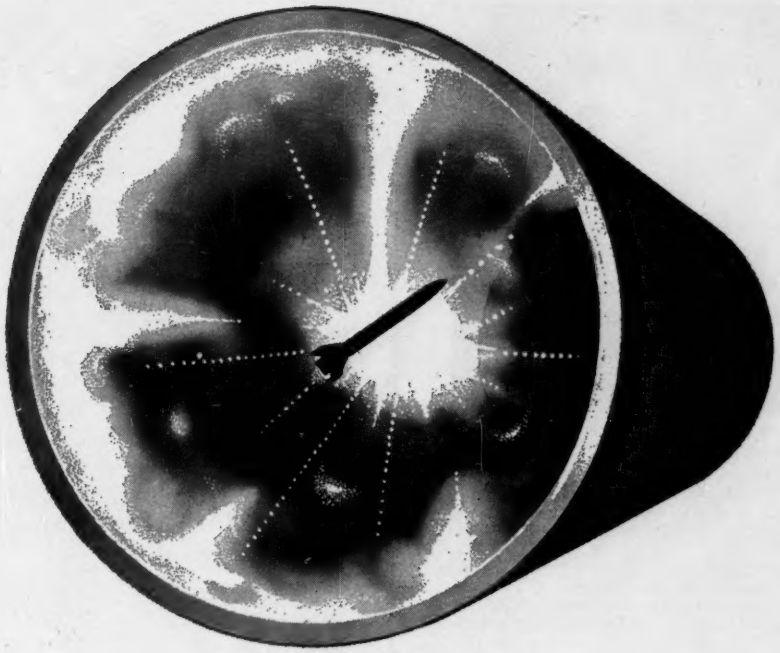
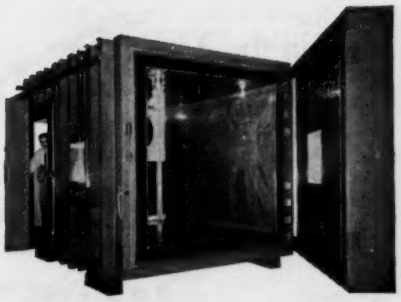


You name the environment ...TENNEY will simulate it!

Altitude, heat, cold, explosion, vacuum ... whatever environment you need, there is an extensively-tested Tenney prototype already built that is very near your specifications. By adjusting the prototype to fit your particular requirements, we can make delivery in a surprisingly short time. In operation, your Tenney chamber will reach ideal environmental conditions quickly, maintain them efficiently throughout the test run, and provide accurate data for quick, simple evaluation.

Tenney, pioneer in the science of environmental testing, is today the world's largest, most experienced creator of environmental testing equipment. Write today for literature describing Tenney's complete line of prototype chambers, or for information on Tenney's research and development, engineering consultation, and design services.



Tenney
ENGINEERING, INC.
1090 SPRINGFIELD ROAD, UNION, N. J.

PLANTS: UNION, N. J. & WILMINGTON, NO. CAROLINA • There is a Tenney Chamber to simulate altitude, heat, cold, humidity, vacuum, explosion, sand, dust, fog, and most other environmental conditions.

CIRCLE 51 ON READER-SERVICE CARD

YOU CAN OWN THIS VALUABLE AUTHORITY ON PERMANENT MAGNETS FOR *ONLY* $10. You'll find the answers to almost all of your questions about permanent magnets in this authoritative Crucible handbook — because its 346 pages cover everything from selecting magnet alloys for TV systems to interpreting molecular fields.

Just look at the chapter headings: Permanent Magnet Design • Permanent Magnet Measurements • Theory of Ferromagnetism • Electromagnetism • Permanent Magnet Steels • Cast Alnico • Permanent Magnet Alloys • Standard and Stock Magnets • Ferrimag • Magnetization and Demagnetization.

For your copy, send check or money order for $10* *to Crucible Steel Company of America, Four Gateway Center, P.O. Box 88, Pittsburgh 30, Pa.*

**Add 40¢ for state sales tax if you are located in Pennsylvania.*

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BRASS
CARBORUNDUM
CERAMIC
COBALT FERRITE
COPPER
*CORNING 707
*CORNING 7052
COPROUS BROMIDE
FERRITE
FERROX
**FLUORIDE, CALCIUM
**FLUORIDE, LITHIUM
GALLIUM ANTIMONIDE
GALLIUM ARSENIDE
GARNET
GERMANIUM
GOLD
INDIUM ANTIMONITE
INDIUM PHOSPHIDE
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MAGNETIC PLUMBITE
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PLATINUM
POTASSIUM BROMIDE
*PYREX
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*QUARTZ, FUSED
**SAPPHIRE
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**STEEL
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*VYCOR
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ALL TYPES KNOWN GLASS

* Carried in stock
** Purchased for orders

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MANMADE SOLAR RADIATION...

If your need is to duplicate the spectral qualities of solar radiation... blast a pinpoint of collimated light through an optical system spread it evenly over a large surface pack it into a tight spot or pour on the beam candlepower efficiently, you should investigate Xenon gaseous discharge lamps by Osram. These Xenon lamps are available in XBO point source design and in the XBF diffuse design in wattages ranging from 150 watts to 6000 watts.

For spectral energy distribution data, prices, recommended wiring diagrams, or information on power supplies, please address inquiries to Macbeth Sales Corporation, sales representative for Osram Xenon lamps in the United States. O.E.M. prices on request.

P.O. Box 950, **MACBETH SALES CORPORATION** Newburgh, N. Y.

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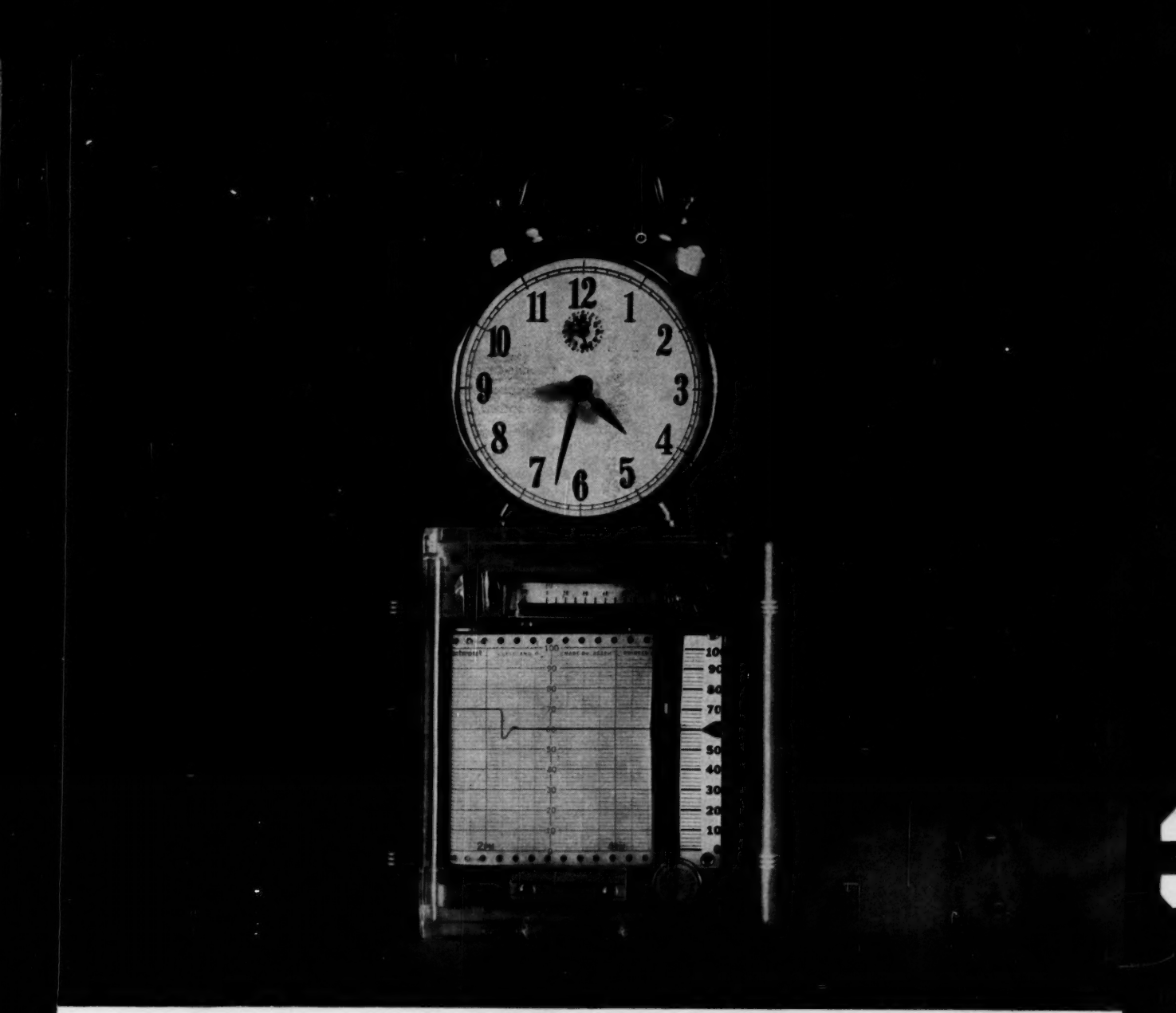

654 MILLION HOURS ON-STREAM; NO TIME OFF FOR MISBEHAVIOR

Ten years ago, the first Autronic® loop went on-stream. It has since been joined by more than 20,000 others. These loops have rolled up 654 million service-hours, measuring, indicating, recording, and controlling every conceivable process variable.

In all that time, very few have required more than token service—the change of a circuit card, a screwdriver calibration adjustment, that's all.

There's good reason for this successful record: Swartwout people are thoroughly oriented to electronic control. They know its advantages. They know its pitfalls, too . . and how to avoid them.

If you are considering making your next control loops electronic (and most people are), Swartwout's unique experience, backed by the most complete selection of equipment in the industry, can assure on-stream success.

More information? Send for Bulletin A-913.

SWARTWOUT

SWARTWOUT DIVISION, CRANE CO.

HOOKSETT INDUSTRIAL PARK • MANCHESTER, NEW HAMPSHIRE

SWARTWOUT . . . World Leader in Electronic Process Control

moving fast with CRANE

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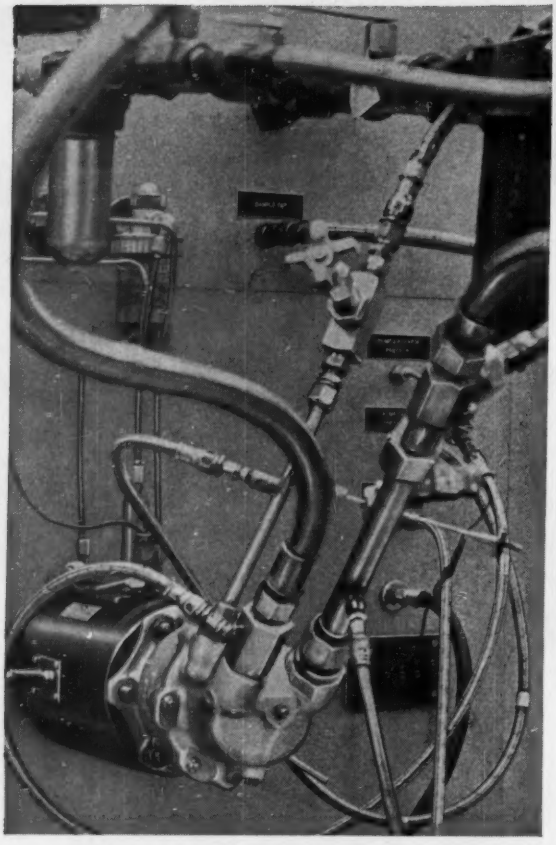


BENDIX BOUGHT THIS TORQUOMETER

When The Bendix Corporation needed torquometers capable of sensing torque on eight production test stands for hot-fluid hydraulic pumps, they chose the B & F Model CB3.

Here's why—

- High Output . . . "gage factor" of 50
- Torquometer alone supports the load
- No adapters . . . Pad Type Couplings (to AND specs.), for ease in changing pumps
- Continuous operation at 350°F

This torquometer can measure up to 10,000 in. lb. of torque, at continuous speeds up to 10,000 rpm. We also produce other Torquometers capable of measuring torques from 0-1 in. lb. to 30,000 in. lb. full scale, at speeds in excess of 20,000 rpm.

B&F instruments, Inc.

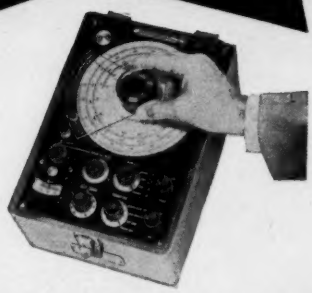
3644 N. Lawrence Street
Philadelphia 40, Pa.
GArfield 5-4175

Torque Meter Systems, Accelerometers and other equipment for data acquisition

CIRCLE 56 ON READER-SERVICE CARD

MODEL 9B PYROTEST

The Most Versatile Portable Potentiometer Made



- **Checks any thermocouple-actuated instrument**
- **Guaranteed accuracy— ⅛ of 1%.**
- **9 interchangeable, direct-reading scales**

Pyrotest is the only portable potentiometer that can check any thermocouple-actuated indicator, controller, or recorder. It comes with 6 thermocouple scales and 3 MV scales—as easy to change as phonograph records. Scale length of over 4 feet, with high resolution to match. Pyrotest is so accurate, it's used as a standard in the lab . . . so versatile and rugged, it's used as an all-purpose tool everywhere in the plant. Only $315.00, fob Indianapolis. Write for free Bulletin 9-B.

TECHNIQUE

TECHNIQUE ASSOCIATES

A Division of Duncan Electric Co., Inc.

1413 CORNELL • INDIANAPOLIS 2, INDIANA

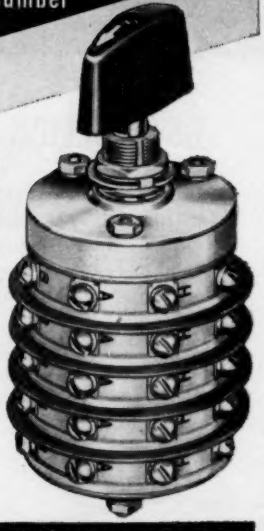
CIRCLE 57 ON READER-SERVICE CARD

TYPE JL ROTARY SWITCH

meets MIL specification MIL-S-21604 and BuShipsDrawing Number 9000-S6202-744 2

ESCO

Maximum of eight contact positions and up to ten sections, controlled by a single knob.



Type JL rotary switch provides unlimited rotation in both directions. Movement can be limited to any number of eight positions by two stop screws.

Designed for single-hole panel mounting.

Electrical Rating: 5 amperes, 125 volts a-c.

Write for Bulletin No. 10

ESCO of WEYMOUTH

ELECTRO SWITCH CORPORATION

167 King Avenue, Weymouth 88, Massachusetts

CIRCLE 58 ON READER-SERVICE CARD

Solve Multi-Point Temperature Control Problems...

at ⅔ cost of competitive systems

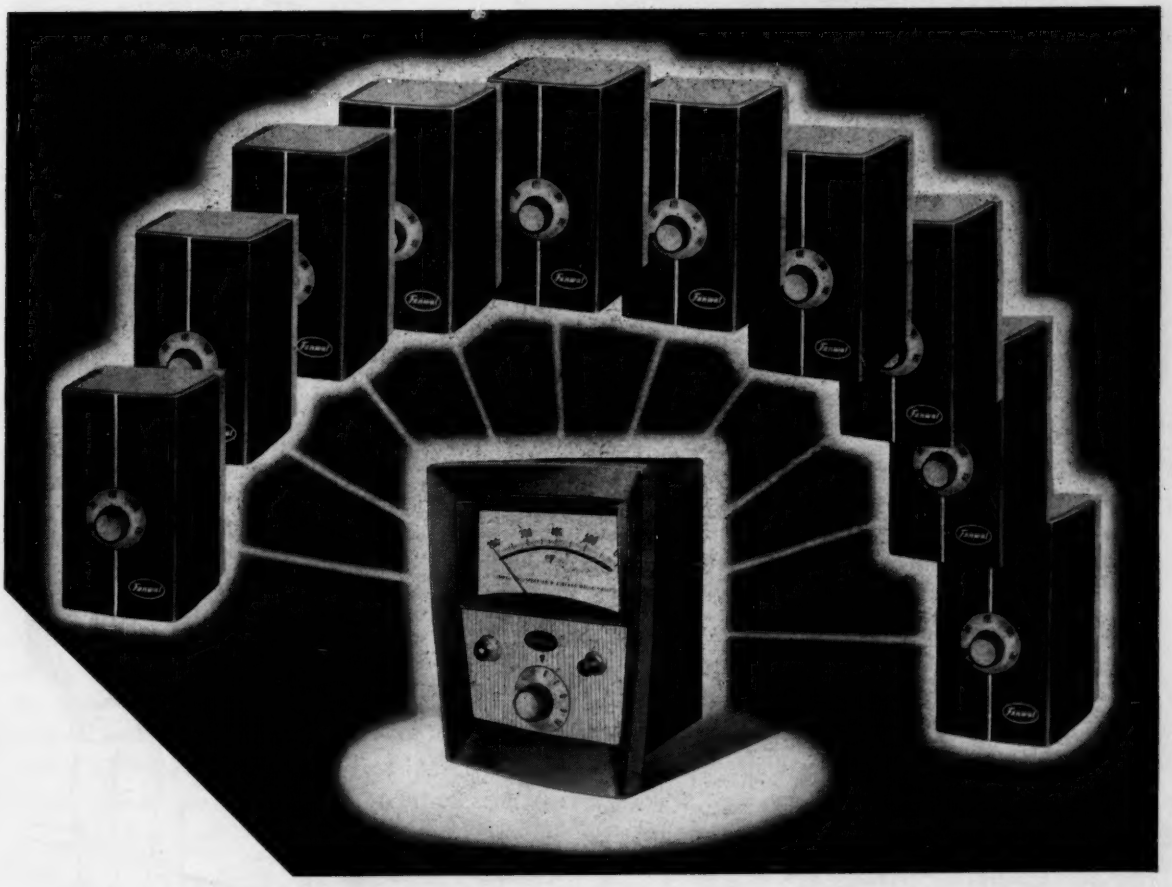
You get them all — wide ranging versatility . . . maximum sensitivity . . . easy installation and servicing! These features *combine* in a Fenwal 536-580 multi-point monitoring system to give you precise, transistorized temperature control and indication. And *you choose the features you need to suit your own requirements!*

Examine these cost saving advantages: Indication and control circuits are separate . . . the 536-580 system eliminates the need for separate indication and control at each point. You can build a control system concurrent with your needs — start with 2 points and build up to 10 points without paying a premium at the outset. The complete control system is built from *standard* catalog parts, thereby eliminating the need to buy costly "specials" for servicing at a later date.

Individual points can have either proportioning or ON/OFF control modes. The system permits "flick of switch" indication of from 2 to 10 temperatures. Individual set points can be adjusted from a central control panel or through a separate potentiometer remotely located. You select your own number of points and you *pay only for the options you use.*

Choose from five standard temperature ranges — from −50 to 600°F . . . expanded scales permit fine temperature adjustments and improved readability, and *the entire system gives you sensitivity to within 0.1°F.*

Both instruments are smartly styled to perfectly complement modern industrial machines and interiors. A Fenwal engineer will be glad to supply information on this system, or any other temperature control in Fenwal's broad line. Write Fenwal Incorporated, 364 Pleasant Street, Ashland, Mass.



Another example of how **Fenwal** CONTROLS TEMPERATURE . . . PRECISELY

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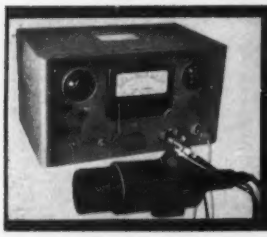
WHERE HEAT CONTROL IS CRITICAL



PYROTEL RADIATION PYROMETER

MONITORS, CONTROLS PRECISELY

Instantaneous, accurate temperature readings on even inaccessible, moving or fragile objects are now possible with non-contacting **PYROTEL** radiation pyrometer.

Operable, precise and dependable at distances from 1 inch to 100 feet or more, **PYROTEL** offers perfect control in heating processes. **PYROTEL** gives meter indication, recording output and relay and load controls

Models for all temperature ranges from 140°F up have proven extremely dependable and profitable in an unusually wide variety of applications. These include extrusion, hot forming, web drying, forging, heat treating, melting, hardening and other processes.

Write for complete information.

MASON INSTRUMENT COMPANY, INC.

222 Valley Place, Mamaroneck, N. Y.

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NEW NEW NEW NEW NEW NEW NEW NEW NEW

when it

MELTS

you know the *temperature!*

NEW *Markal* THERMOMELT TEMPERATURE INDICATORS

With Handy Adjustable Holder

The easy modern way to determine exact working temperatures!

Just mark or stroke the surface with THERMOMELT . . . when it reaches the desired temperature, the mark liquefies. There's no guesswork, no wasted time or material . . . THERMOMELT is the quick, precise way to determine heating temperatures. Accurate to within ±1%.

A Stik For Every Temperature from 113° F. to 2000° F.

SEND TODAY for free THERMOMELT literature and pellet sample (indicate temperature desired).

ALSO AVAILABLE IN LIQUIDS AND PELLETS for inaccessible or hard-to-measure applications. Wide range of temperatures.

Made by the Manufacturers of Markal Paintstik Markers and Protective Coatings.

MARKAL CO. 3080 West Carroll Avenue • Chicago 12, Illinois

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THE ORIFICE PLATE

primary element in flow metering, stands on its ability to provide an accurate, reproducible signal. This signal is paramount in differential measurement. Such a signal can be achieved only with orifice plates of quality stainless steels, stretcher-leveled for flatness, precision bored to a knife-edge by expert craftsmen. Your orifice meter deserves to get the best possible signal. We stand on our reputation to provide the best possible orifice plates.

DANIEL ORIFICE FITTING COMPANY

Orifice Plates—Daniel Catalog Section "G"

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- 3352 Union Pacific Ave. LOS ANGELES 23, CALIF.
- ODESSA
- DALLAS
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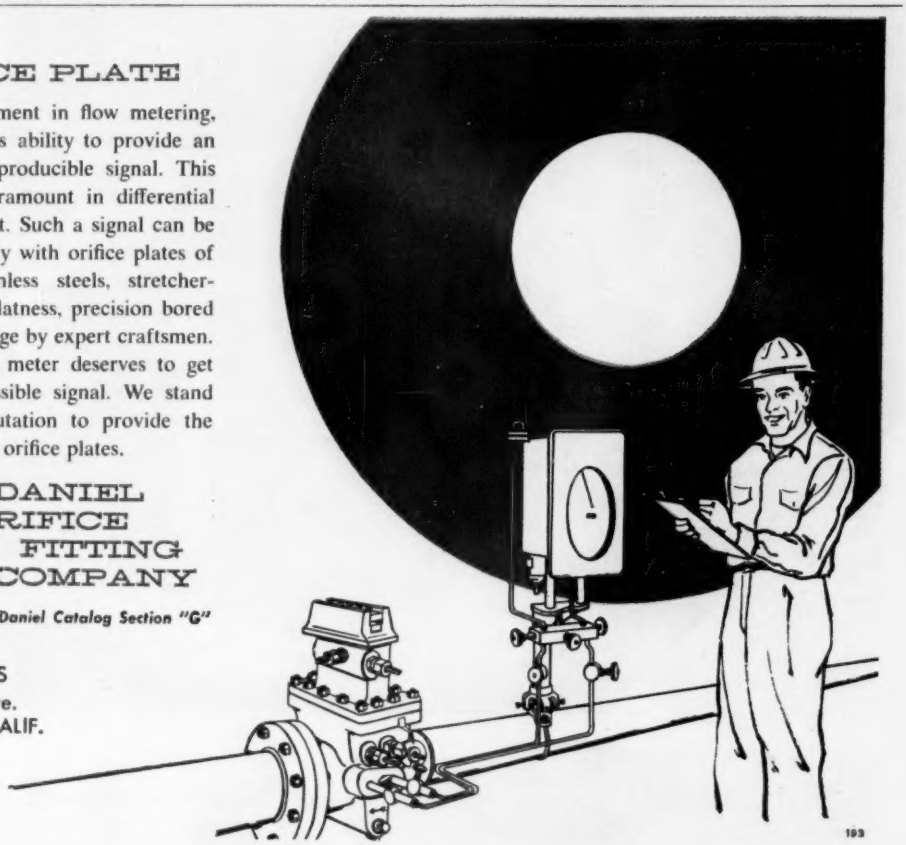
- TULSA
- NEW ORLEANS



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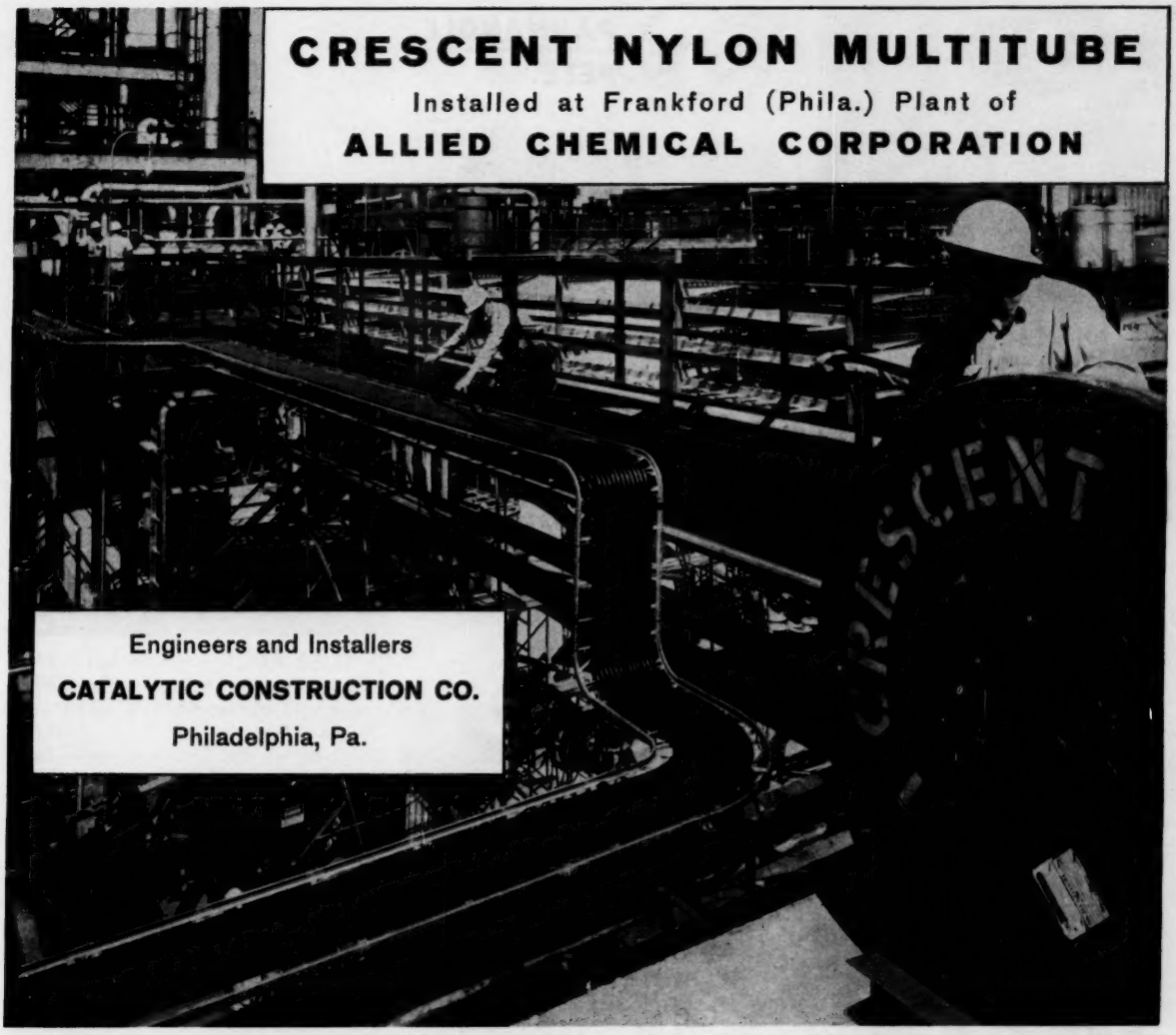
CRESCENT NYLON MULTITUBE

Installed at Frankford (Phila.) Plant of

ALLIED CHEMICAL CORPORATION



Eight miles of CRESCENT NYLON Tubing made from Allied Chemical Corporation's PLASKON® NYLON, in the form of MULTITUBE, is installed in this large chemical plant for purposes of instrument control.

Each MULTITUBE cable shown in this picture contains 14 nylon tubes spirally cabled together, which permits maximum bending without distortion of the tubes. The assembly is protected by a Mylar® tape, as well as a weather, corrosion and flame resistant PVC thermoplastic sheath.

Nylon Tubing offers excellent resistance to environmental deterioration, impact and abrasion coupled with unusually high fatigue resistance over a broad temperature range. It is less expensive than copper tubing, and is particularly easy to install. Individually numbered tubes, with numbers clearly visible every 2 inches, make it easy to identify tubes at either end.

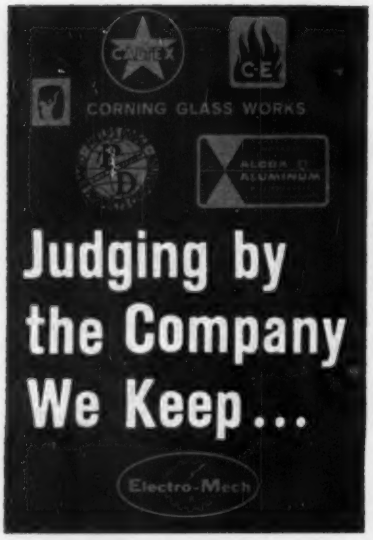
CRESCENT makes many types of MULTITUBE, using copper, aluminum, steel, polyethylene or nylon tubes, with a great variety of protective sheaths, including interlocked metal armor.

Send for NEW Bulletin No. 960-A with complete engineering data, diagrams, etc.

CRESCENT INSULATED WIRE & CABLE CO.

Trenton 5, New Jersey

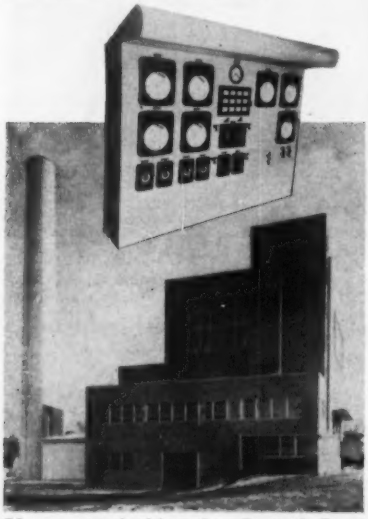
CIRCLE 63 ON READER-SERVICE CARD



THE COMPANY WE KEEP—

also includes many municipalities.

To meet the pressing need for more efficient community facilities, Electro-Mech Corporation has been called upon repeatedly as an authority, specializing in the field of design and manufacture of control systems for Water Treatment, Sewage Treatment and Incineration . . . vital aspects in the health and welfare of our expanding American towns and cities.



If you are looking for Control Systems engineering, design assistance, or control center manufacturing facilities, we invite you to join the "Company We Keep" . . . . . Contact ELECTRO-MECH.

Electro-Mech Corp., Norwood, N. J.

Electro-Mech

CIRCLE 64 ON READER-SERVICE CARD

PANHANDLE PETE

The Instrument Salesman—

9:00 AM. (okay, so I didn't get in the office until 10:20—was it my fault my car wouldn't start?) Before I line up my calls for the day I'll look at this copy of INSTRUMENTS magazine and find out what's happening in the field of symbolic logic. Just love that symbolic logic. Wonder what symbolic means?

11:30 AM. There sure was some good articles in that issue. Especially those with all that math. Wish I knew Greek or French—then I'd know what them deltas and Loplaces mean. Before I line up my calls for the day, I'll have just one for the road. This instrument racket is tough on the nerves even if I am a systems engineer now instead of an instrument peddler.

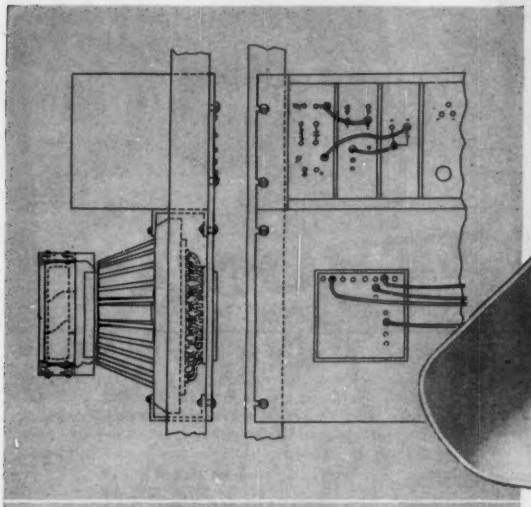
12:00 Noon: No use going out now. It's lunch time. The orifice in this little toy could make a fine pneumatic amplifier if we hooked a position-sensitive flapper-nozzle unit with a bellows relay between the nose and the base. Then a little bottle of gas would make it jump all over the place. Think I'll try it out.

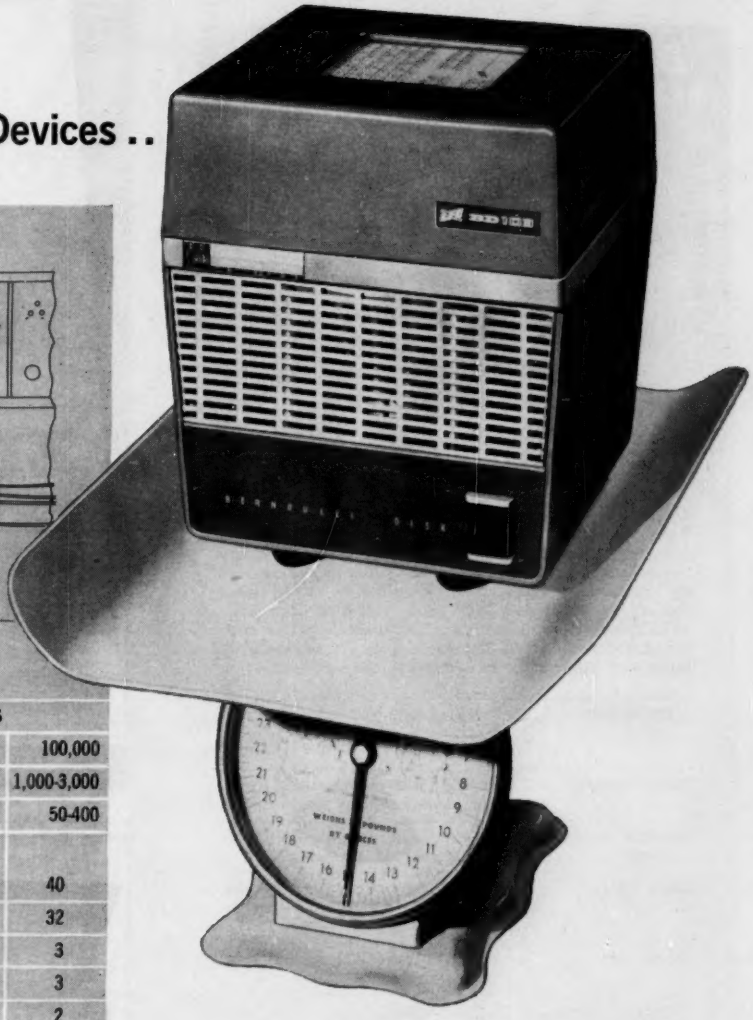
2:00 PM. Well it jumped this far as soon as I hooked up the air, but the flapper stuck and the bugger blew up. That was fun. It's a little late for going on the road today. Guess I'll have just one more.

4:00 PM. I'm tired of getting pushed around this lousy organization. Systems engineers don't grow on trees. I want a raise. Where's the boss?

Panhandle Pete

In Rotating Storage Devices..





SPECIFICATIONS BD-100 SERIES	
Storage Capacity Nominal Bits	100,000
Bits Per Track	1,000-3,000
Bit Rate — kc	50-400
Track Layout As Required	
Typical:	
Total Tracks:	40
Data Storage Tracks	32
Spare Track	3
Clock and Timing Track	3
Register Track	2
Number of Registers	4
Register Length — Bits	32
Register Adjustment — Bits	±3
Disk Speed — RPM Induction or Synchronous Motors Available	1800-8000
Power Source — cps	60-400
Magnetic Heads (Compatible with solid state circuits)	
Typical: (For 200 kc Operation)	
Inductance (Per Leg. — C. T. Coil) — uh	55
Write Current (O/P Manchester) — ma	125
Read Out (Min. P/P Full Coil) — mv	20
Size — Inches (Less Electronics)	9 x 9 x 5
Weight — pounds	
Basic unit	15
With electronics	25

Wide variations from typical specifications can be made to meet customer's requirements.

...LFE Bernoulli Disks Deliver More Reliability Per Pound!

No other rotating storage device can match the LFE Bernoulli-Disk Memories for small size, light weight, low cost and high resistance to shock, vibration and temperature changes.

Simplicity is the key! A flexible magnetic disk, headplate and precision motor are the basic components. Positive separation between disk and headplate is maintained by centrifugal force and Bernoulli principles of fluid motion. The unit's low mass plus a cushion of air make damage to disk or read/write heads virtually impossible under even the most severe environmental conditions.

Available in standard customized models for bench or rack mounting, the BD-100 Series (illustrated) is compatible with all fixed station or mobile digital computers utilizing magnetic storage media. For complete information, please write Sales Manager, Data Storage Operations.

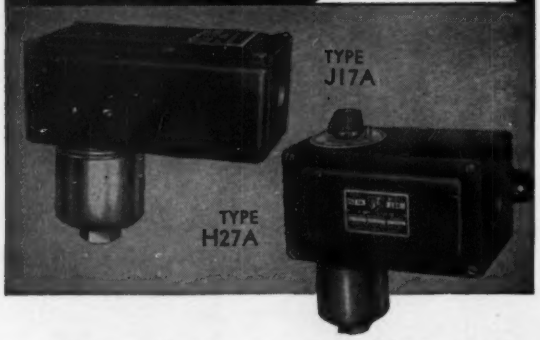
LFE
COMPUTER PRODUCTS DIVISION

LABORATORY FOR ELECTRONICS, INC.
1079 COMMONWEALTH AVE. • BOSTON 15, MASSACHUSETTS

CIRCLE 65 ON READER-SERVICE CARD

Dual Switch PRESSURE-VACUUM CONTROLS

J17A | H27A



UNITED ELECTRIC's Types J17A and H27A Pressure-Vacuum Controls are similar units that have been designed for applications where it is desirable to control two separate circuits at different pressures by means of a single control unit. The major difference between the J17A and H27A is that the J17A contains an uncalibrated adjustment while the H27A has a calibrated dial and single turn adjustment knob and pointer for making pressure settings.

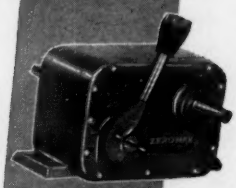
Adjustable Range	Various ranges between 30" Hg vac and 180 psi limits. H27A is calibrated.
Switch Differential	Factory pre-set for values of 1" Hg to 1 psi, dependent upon model.
Differential Between Switches	Factory pre-set for values of 3" Hg to 4 psi, dependent upon model.
Switch Ratings	Up to 15 amps. at 115 or 230 volts A.C. 20 amp. A.C. or D.C. switches also available.
Switch Types	N.O., N.C., or Double Throw — no neutral position.
Maximum Pressure	Up to 180 psi.
Electrical Connections	Lead wires attached to internally located terminal blocks via a 7/8" opening.
Pressure Connections	Via a 1/4" female NPT on the bellows housing.
Enclosure	Die cast aluminum with a black wrinkle finish and a brass bellows housing.
Mounting	J17A — Via pressure connection. H27A — Via pressure connection or holes in two dog ears.

UNITED ELECTRIC ***manufactures a complete line of temperature, pressure, and vacuum controls. For special applications, standard units may be modified, or custom-built units can be provided. For additional data on standard pressure-vacuum controls, including Types J17A and H27A, request*** Section 300 *of our* new *catalog.*

U.E. United Electric Controls COMPANY
85 SCHOOL STREET WATERTOWN MASS

CIRCLE 66 ON READER-SERVICE CARD

STEPLESS VARIABLE SPEED



ZERO-MAX

FREE COPY

NEW VARIABLE SPEED CATALOG

Here's all you have to know about fhp variable speed. Explains the Zero-Max principle with pictures and diagrams of uses. Describes over 30 basic models and types of Zero-Max drives which deliver 0 to 1200 rpm and up to 450 in. lbs. torque.

WRITE FOR YOUR FREE COPY TODAY!

ZERO-MAX The ZERO-MAX Company
2885 Harriet Ave. S., Minneapolis 8, Minn. • TAylor 7-5521

CIRCLE 67 ON READER-SERVICE CARD

PRECISION JEWEL BEARING ASSEMBLIES . . .

for AIRCRAFT • ELECTRICAL MECHANICAL and MARINE INSTRUMENTS

Sapphires set in brass, or other metal assemblies made in any quantity to close tolerance specifications are produced by Moser Jewel Company—*manufacturers of industrial jewels for over 50 years.*

Moser also provides highly polished pivots, staffs —silicon and spring loaded assemblies for high shock resistance.

SEND SPECIFICATIONS — DETAILED INFORMATION READILY GIVEN.

MOSER JEWEL COMPANY
P.O. Box 150 • Perth Amboy, N. J.
"Manufacturers of all types of Industrial Jewels"

CIRCLE 68 ON READER-SERVICE CARD

NOW
THE FAMOUS "NO MAINTENANCE" PRESSURE REDUCING VALVE WITH NEW STEEL BODY

The Leslie GP-type pressure reducing valves are recognized as the simplest, most rugged, most maintenance-free ever made. Sold under Leslie's famous 3-year no-maintenance guarantee, they have so far been available with cast iron or cast bronze bodies only.

To satisfy the heavy demand for GP performance and construction features in 150, 300 and 600 lb. steel-body valves, here is the new Class GPS valve in carbon steel and alloy steels for steam, air, gas and other vapors.

The design still uses only two moving parts—a Spiroflex diaphragm and the main valve. These are virtually indestructible. There is nothing to wear out.

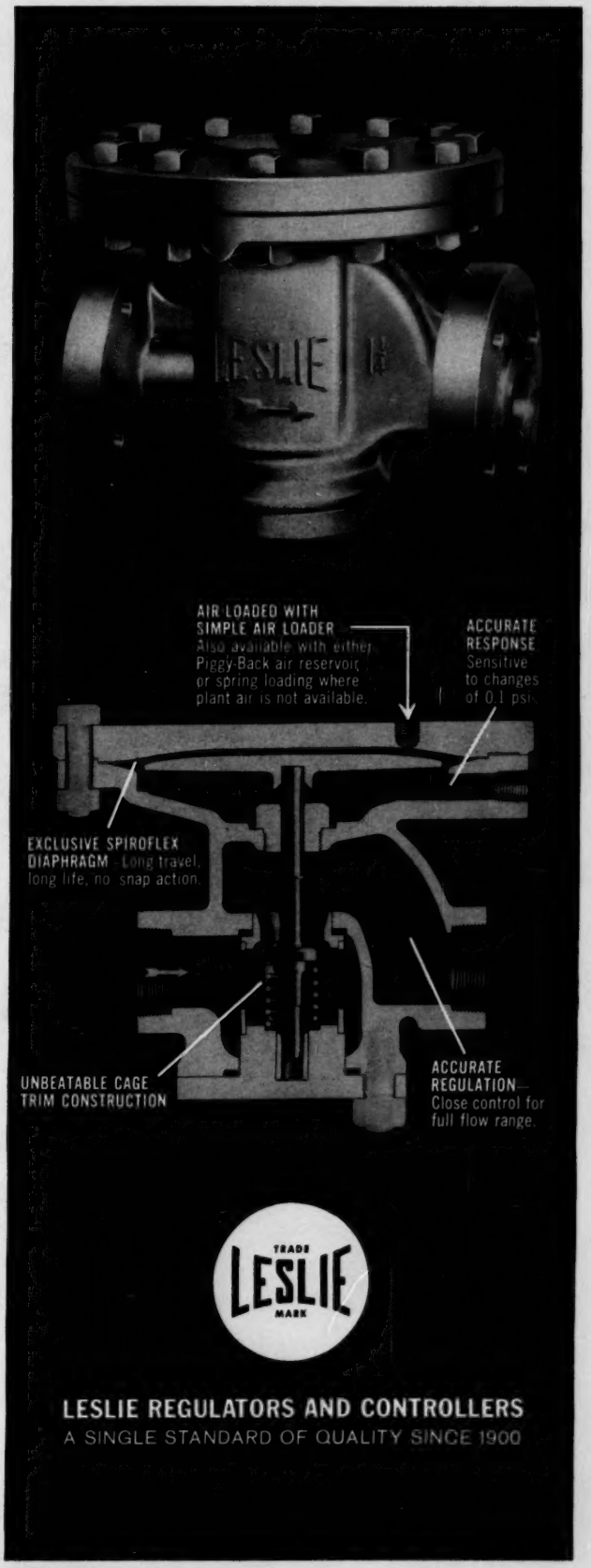
The low-stress diaphragm is the patented Leslie-Spiroflex®, which flexes like rubber but resists temperature as only a metal diaphragm can. Look at the cage trim construction—proved in Leslie-Lifetime control valves. Hardened stainless steel main valves seat on easily renewable, "permanent" type, stellited seat inserts. An unbeatable combination for long, trouble-free life.

The man to show you how much money this design will save you is your nearest Leslie Engineer. He is listed in the Yellow Pages under "Valves" or "Regulators." You will also want to send for our Product Data Sheet No. 611.

SPECIFICATIONS—Reducing Valve, GPS Classes

Sizes: ½" to 2" screwed or welding ends, or 150 lb., 300 lb. and 600 lb. flanges in carbon steel and alloy steels. Inquire about 2½ to 4" sizes soon to be available.
Diaphragm: Leslie-Spiroflex®, Stainless Steel.
Main Valve: Type 440C Stainless Steel, hardened.
Seat Ring: Stainless Steel, Stellited.
Stem Guides: Gun Metal Bronze (top and bottom guided).
Main Valve Spring: Inconel.
Inlet Pressure Range: 600 psi, 600°F.
Reduced Pressure Range: 0-300 psig.
Minimum Pressure Drop across Valve: ½ psi.

Leslie Co., 704 Grant Ave., Lyndhurst, New Jersey

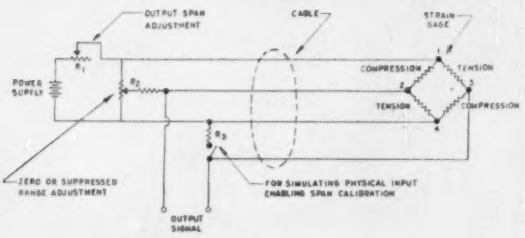

LESLIE
AIR LOADED WITH SIMPLE AIR LOADER
Also available with either Piggy-Back air reservoir or spring loading where plant air is not available.
ACCURATE RESPONSE
Sensitive to changes of 0.1 psi.
EXCLUSIVE SPIROFLEX DIAPHRAGM
Long travel, long life, no snap action.
UNBEATABLE CAGE TRIM CONSTRUCTION
ACCURATE REGULATION—
Close control for full flow range.
TRADE LESLIE MARK
LESLIE REGULATORS AND CONTROLLERS
A SINGLE STANDARD OF QUALITY SINCE 1900

LC-43

CIRCLE 69 ON READER-SERVICE CARD

BRIEFS

Transducer Performance



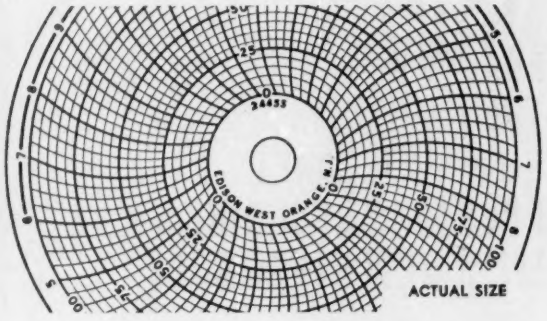
Schematic of Calibration Technique

Transducer performance has been defined in various ways; however, certain parameter definitions have evolved into more or less standard terms. For adequate performance analysis, these callouts should be a part of equipment specifications: Resolution, Nonlinearity, Hysteresis, Thermal Zero Shift, Thermal Coefficient of Sensitivity, Long Term Zero Shift, Resonant Frequency, Acceleration Response . . . (*From 24-page brochure, "Transducers for Industrial Instrumentation," Statham Instruments, Inc., 12401 W. Olympic Blvd., Los Angeles 64, Calif.*)

FOR THIS LITERATURE CIRCLE 191 ON READER-SERVICE CARD

3" Circular Chart Recorder

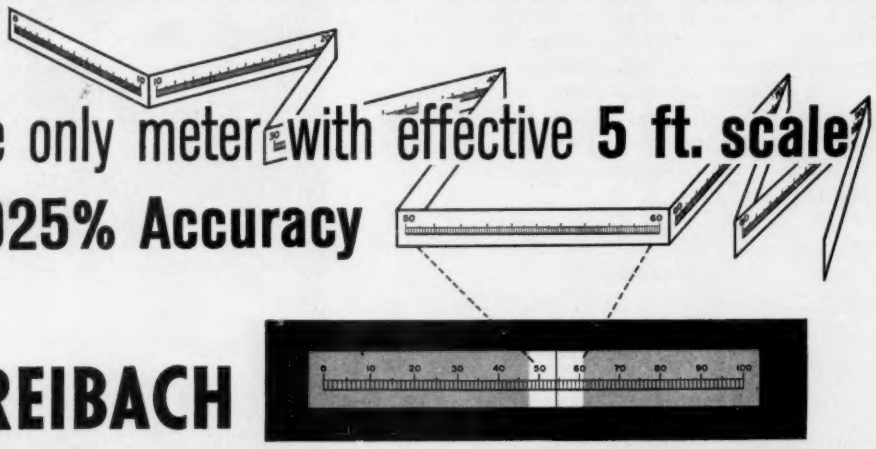
The Model 400 OMNICORDER is a circular chart recorder so small that it can be mounted in the same space as a conventional meter. Housed in a molded



plastic case only 3¾" x 3¾" x 3" deep, it can be mounted on 4" centers so that 9 recorders can be mounted in a panel area of only one square foot.

This rugged instrument will record electrical voltage, current, or power, or any variable which can be converted to an equivalent electrical signal. No pen, ink or ribbon is required, the graph being printed by means of a stylus on a pressure sensitive paper. The 3" chart is remarkably legible and standard charts measure a wide range of variables . . . (*From 8-page Bulletin 3057, Thomas A. Edison Industries, Instrument Div., Lakeside Ave., West Orange, N. J.*)

FOR THIS LITERATURE CIRCLE 192 ON READER-SERVICE CARD



NEW the only meter with effective **5 ft. scale** and **.025% Accuracy**

GREIBACH

SELECTIVE EXPANSION PRECISION METERS

Read direct, then expand! No guesswork, no hunting for scales, no missed readings! Take your sample quickly, then expand the 10-divisions you want to a full length 100-division scale. Read the 3rd significant figure **exactly** . . . estimate the 4th figure! Single and multi-range combinations are available in one compact meter . . . for panel or portable use. In addition it includes all of the well-known Greibach features: no-friction Bifilar movement and weightless light beam pointer, with inherent durability, ruggedness and extraordinary overload capacity. For full details on "Selective-Expansion" and other Greibach precision meters, write, wire, phone today for our complete 20-page Catalog.

GREIBACH INSTRUMENTS CORPORATION

331 North Avenue, New Rochelle, N. Y. Phone: NEw Rochelle 3-7900

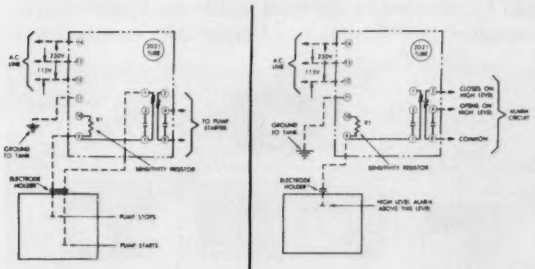
CIRCLE 70 ON READER-SERVICE CARD

Sec. 2900

Liquid Level Controls

B/W electronic floatless liquid level controls have been designed to provide a new high standard of versatility and reliability in measuring and regulating a wide variety of high and low resistance liquids . . .

INVERSE OPERATION

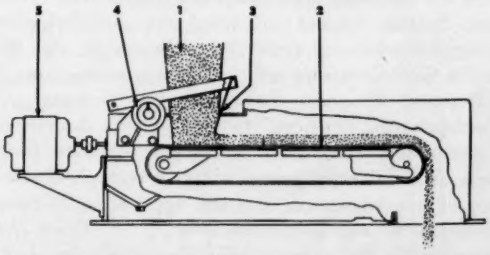


Pump Up — High Level Alarm

Type 50-201 is designed primarily for use with liquids of medium and high specific resistance—up to 5.5 megohms on direct operation installations and 12.5 megohms where inverse operation is desired . . . Type 50-101 is particularly well suited to applications where very low electrode potentials and currents are desired to eliminate shock and sparking hazards as well as contamination of liquids due to electrolysis . . . Positive fail-safe control may be obtained by wiring to the terminals for direct or inverse operation . . . In direct operation, the relay is energized when the electrode is contacted by the liquid and electrode current is flowing. In inverse operation (shown) the relay is energized when the level of liquid drops below the electrode and electrode current ceases to flow . . . (*From 4-page Bulletin 334, B/W Controller Corp., 2200 E. Maple Rd., Birmingham, Mich.*)

FOR THIS LITERATURE CIRCLE 193 ON READER-SERVICE CARD

Vertical Gate Type Volumetric Feeder



The material being fed enters the feed section (1) from an overhead hopper or chute, falls on the endless feed belt (2) and then passes beneath the vertical gate (3). The position of the vertical gate determines the volume of material passing through the Feeder. By raising or lowering the gate, volume is increased or decreased. The gate is positioned by a manually controlled feed rate adjustment (4) (simple dial with a knob and pointer). The dial is graduated in per cent indicating feed-gate opening . . . (*From 4-page Catalog 320.200, Wallace & Tiernan Inc., 25 Main St., Belleville 9, N. J.*)

FOR THIS LITERATURE CIRCLE 194 ON READER-SERVICE CARD

"PACKAGED" PROTECTION FOR YOUR CONTROLS

Frame: 24" deep, 24" wide, 63⅜", 70⅜" or 84⅜" high

Front panel space: 56", 63", 70" or 77" high

New Honeywell Modu-Mount* Cabinets

Now you can get standard enclosures to protect your valuable precision instruments and devices. New Honeywell Modu-Mount Cabinets are designed by experts to provide the ultimate in appearance, convenience and economy. Best of all, you can order them to fit your specific enclosure requirements.

The rugged steel frame can be left open or enclosed by panels and doors. You can specify such features as anti-tilt mobile base, wiring trough, lift-bars and eyebolts, or floor levellers, vibration mounting and cooling louvers. And up to five Modu-Mount Cabinets can be supplied with a common base and wiring trough.

Modu-Mount Cabinets come in standard green, grey or brown baked enamel. Other colors are available at your request. For details, call your nearby Honeywell office. Or write Honeywell, Dept. IC-4-55, Minneapolis 8, Minnesota. *Sales and service offices in all principal cities of the world.*

HONEYWELL CUSTOM ENCLOSURES

Honeywell will design and custom-build any cubicle, panel, console or other enclosure to your exact specifications. Special attention is given to these orders, and the finished product meets the most stringent requirements.

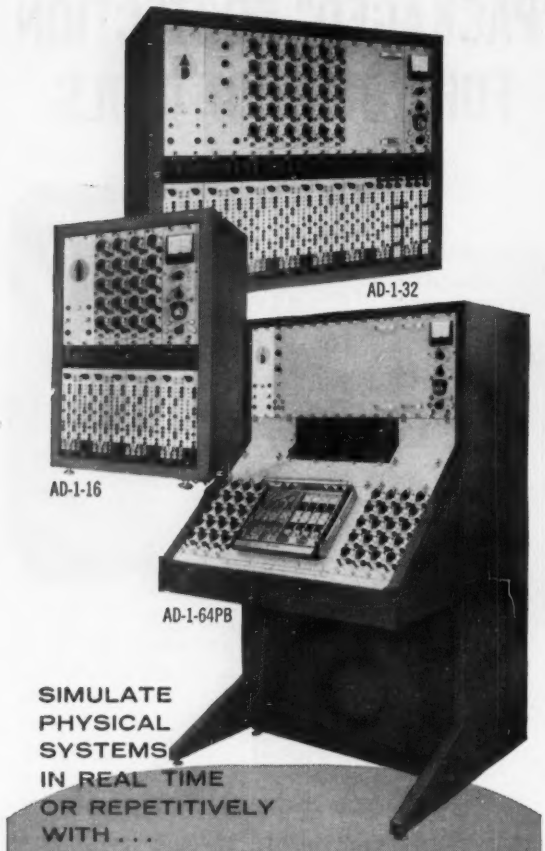
Honeywell

First in Control

SINCE 1885

*Trademark

CIRCLE 71 ON READER-SERVICE CARD



SIMULATE PHYSICAL SYSTEMS IN REAL TIME OR REPETITIVELY WITH . . .

Applied Dynamics Analog Computers SERIES **AD-1**

Modular Design For Plug-in Expandability And Maximum Reliability

- Passive-circuit diode multipliers and function generators
- Computing resistors matched to .01%
- Repetitive operation with electronic reset and simultaneous real-time operation
- Continuous overload monitoring and integral balance check system

AD-1 Series analog computers are available with from 4 to 64 amplifiers for solution of various types of linear and non-linear equations.

The AD-1-64PB features a removable preprogrammed patchboard with up to 64 stabilized amplifiers, 80 coefficient potentiometers, 16 multipliers, 8 function generators, and 20 diode networks.

The AD-1-32 and AD-1-16 feature a fixed patchboard system with up to 32 and 16 amplifier capacity and non-linear equipment for maximum economy.

Modular design permits flexible arrangements to suit various operating requirements.

Applied Dynamics, Inc.

A Subsidiary of Bowmar Instrument Corp.

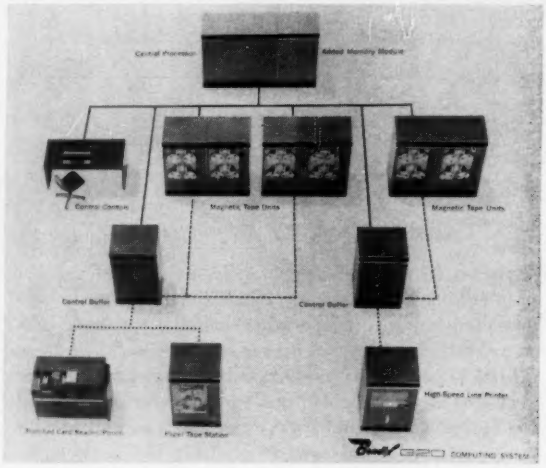
ANN ARBOR, MICHIGAN

Specialists in Industrial and Process Instrumentation and Controls

CIRCLE 72 ON READER-SERVICE CARD

High Density Recording System for Digital Computers

The new Potter High Density Recording System can record magnetically on a one-inch reel of tape approximately 11 times the amount of digital data that can be recorded by the most widely used conventional computer tape systems . . . Despite data transfer rates



as high as 360,000 alpha-numeric characters per second, via 16 parallel recording channels on one-inch tape, and at packing densities up to 1500 bits per inch, the Potter High Density Recording System actually provides higher reliability than is expected of standard recording methods . . . In a recent test of 40 hours continuous operation, less than two seconds of re-read time were required to recover data lost through transient error . . . More than 20,000 passes over any portion of the tape can be made without losing information, or significantly increasing dropout rate . . .

First application of the Potter High Density Recording System is incorporated in high speed tape transports for use with a Bendix Corporation G-20 Computer System (shown) destined for installation at Carnegie Institute of Technology, Pittsburgh, Pa. The Bendix G-20 Computer will serve there as the core of a Doctoral Program curriculum in "Systems and Communication Sciences," concerned with theories of programming, simulation of human cognitive processes, artificial intelligence, adaptive control, the science of administration, and the application of these techniques to management sciences . . . (*From IRE Press Kit, Potter Instrument Co., Inc., Plainview, L. I., N. Y.*)

FOR THIS LITERATURE CIRCLE 195 ON READER-SERVICE CARD

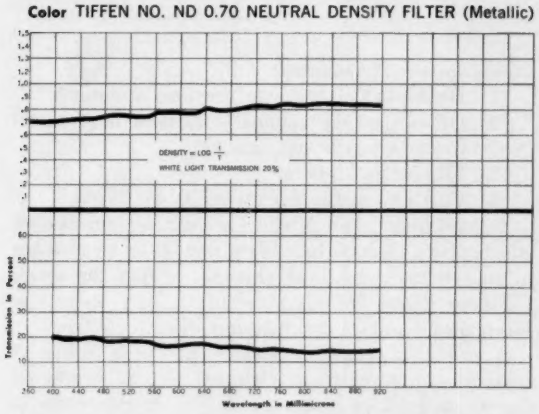
Precision Air Regulation

Slide rule incorporated in a new 24-page catalog on 25 Governaire and Kendall pressure regulators, volume boosters and air relays quickly sizes regulator needed . . . (*Stratos Div., Fairchild Engine and Airplane Corp., Industrial Products Branch, Route* 109, *West Babylon, L. I., N. Y.*)

FOR THIS LITERATURE CIRCLE 196 ON READER-SERVICE CARD

Neutral-Density Filters

Basically, Neutral Density filters reduce the amount of incident light they transmit by a given amount without changing the inherent quality of the light. They have as nearly as possible the same transmit-


Color TIFFEN NO. ND 0.70 NEUTRAL DENSITY FILTER (Metallic)
DENSITY = LOG 1/T
WHITE LIGHT TRANSMISSION 20%
Transmission in Percent
Wavelength in Millimicrons

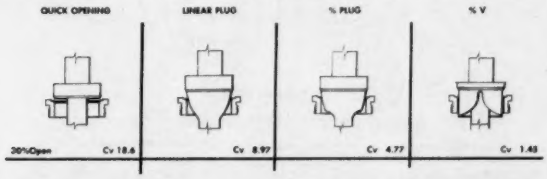
tance for every wave length. An ideal neutral filter would be represented by a straight horizontal line on a transmission graph . . . Because a filter absorbs a portion of the light that otherwise would be available to activate the film emulsion, exposure must be increased when most filters are used. The ratio of exposure required when a filter is used to that required when no filter is used is called the filter factor. Since each F stop is two times greater than the next smaller one the increase in stops is one half the filter factor.

In the case of a neutral density filter the increase in stops may be found approximately by using the following formula, increase in stops = Density/0.301 . . . (*From* 38-*page Catalog* 161, "*Photar Filter Glass,*" *Tiffen Optical Co.,* 71 *Jane St., Roslyn Hts., L. I., N. Y.*)

FOR THIS LITERATURE CIRCLE 197 ON READER-SERVICE CARD

Inner Valve Contours

Super 70 valves employ four basic inner valve contours throughout the line . . . An inner valve contour establishes a constant or a percentage increase in flow



for each equal amount of inner valve lift from closed to fully opened. With these choices, the flow through the valve can be more closely matched with the flow demands made by the process. The quick opening contour is normally used for on-off service . . . If the process demands that the change in flow be constant to maintain "set point," the linear plug is used. If a percentage increase is demanded, the % plug or % V is used . . . (*From* 32-*page Bulletin* 70-275, "*Control Valves,*" *Black, Sivalls & Bryson, Inc.,* 15 *N. Cincinnati, Tulsa, Okla.*)

FOR THIS LITERATURE CIRCLE 198 ON READER-SERVICE CARD

CURTISS WRIGHT

Miniature Recorders

Advanced movement design provides big system features in an exceptionally small instrument. Curtiss-Wright Miniature Recorders combine accuracy, simple operation, reading ease, rugged construction and dependable performance with space and weight saving conveniences.

Send for catalog or phone Swinburne 9-0500.

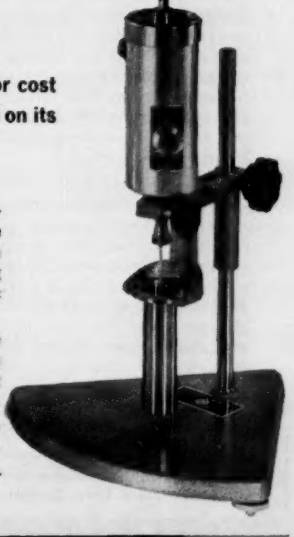
Application and Engineering services available

CURTISS WRIGHT CORPORATION

Princeton Division Princeton, New Jersey

CIRCLE 73 ON READER-SERVICE CARD

Rheology/Viscosity



Does the quality or cost of your product depend on its flow characteristics?

► A complete line of Epprecht Viscometers provide viscosity measurements in the laboratory or during processing with automatic control of viscosity.

► Measurements can be made at pressures up to 700 psi or in a vacuum at temperatures to 300° C.

For detailed technical information on Epprecht Viscometers write to Dept. DV-36.

J. W. FECKER DIVISION

AMERICAN OPTICAL COMPANY

6592 HAMILTON AVENUE • PITTSBURGH 6, PENNSYLVANIA

CIRCLE 74 ON READER-SERVICE CARD

So SIMPLE that "Specials" are Likely to be Standard!

A sleeve, raised and lowered within a non-magnetic tube, attracts or releases an Alnico magnet attached to a mercury switch. Basically, this is Magnetrol

MAGNETROL

The World's Most Dependable

LIQUID LEVEL CONTROL

Because of the utter simplicity of Magnetrol's magnetic operating principle, standard models can be easily adapted to meet any special requirements for pressure, temperature or corrosive liquids . . . and usually at little extra cost. This Magnetrol versatility has solved all kinds of tough level control problems . . . and given our engineers wide application experience that can be invaluable to you.

Magnetrol is so simple that failure is all but impossible! Using only permanent, unfailing magnetic force for its operation, there's nothing to wear out . . . no diaphragms or bellows to stiffen and rupture . . . no electrodes to short or corrode . . . no packing to bind or leak. Magnetrol is practically maintenance-free! Magnetrol units are available for controlling level changes from .0025-in. to 150-ft. . . . with multi-stage switching when desired. Send coupon for full details.

MAGNETROL, Inc.

Send Coupon For Full Details

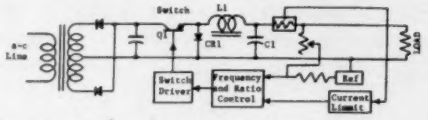
MAGNETROL, Inc., 5326 Belmont Road, Downers Grove, Illinois
Please send me catalog data and full information on Magnetrol Liquid Level Controls. 6

Name .....
Company .....
Address .....
City ..... Zone ..... State .....

CIRCLE 75 ON READER-SERVICE CARD

Solid-State Power Sources

High Efficiency Switching Preregulator plus High Performance Series Regulator provides radical ad-



vances in system planning:

(1) Doubles efficiency over previous optimums.
(2) Offers package volume economies of 4 to 20 times in power supplies.
(3) Eliminates blowers.
(4) Cuts air conditioner capacities by "Tons."

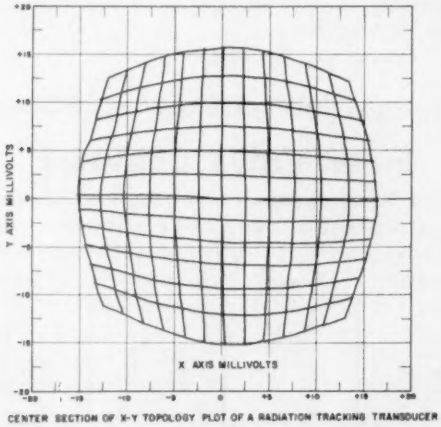
A switching preregulator is an instrumentation which offers essentially lossless regulation to changes in line voltage and load changes so that the series regulator driven by this preregulator may operate at low constant voltage and therefore at high efficiency.

A switching regulator consists of: (1) a source of current, (2) a switch or chopper, (3) an averaging circuit, and (4) a load . . . Recent developments in solid state switching devices and the development of refined control circuitry have made possible more sophisticated power supplies such as described . . . (*From 4-page brochure, Transistor Kinks, Feb.*, 1961, *"Breakthrough in Power Sources," Valor Instruments, Inc.*, 13214 *Crenshaw Blvd., Gardena, Calif.*)

FOR THIS LITERATURE CIRCLE 199 ON READER-SERVICE CARD

Radiation Tracking

The model XY-20 Radiation Tracking Transducer is a novel single-element photovoltaic device that detects position of visible to near infrared radiation simul-

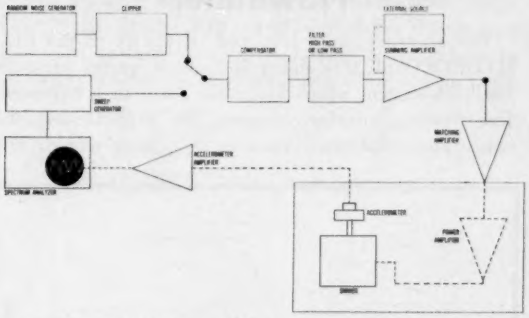


CENTER SECTION OF X-Y TOPOLOGY PLOT OF A RADIATION TRACKING TRANSDUCER

taneously in two axes. Coupled with a lens system, this solid state component is capable of detecting angular position of a radiation source. Extreme versatility makes it applicable to Tracking, Guidance, Computer Application, Instrumentation, and Control Automation . . . The plot (shown) was made by scanning a light spot across the cell surface in a rectangular grid pattern centered on the cell. Lines of the grid were spaced .020 inch apart. The resultant voltage output was recorded on an XY plotter . . . (*From 4-page bulletin, Micro Systems, Inc.*, 319 *Agostino Rd., San Gabriel, Calif.*)

FOR THIS LITERATURE CIRCLE 200 ON READER-SERVICE CARD

Random Vibration Control

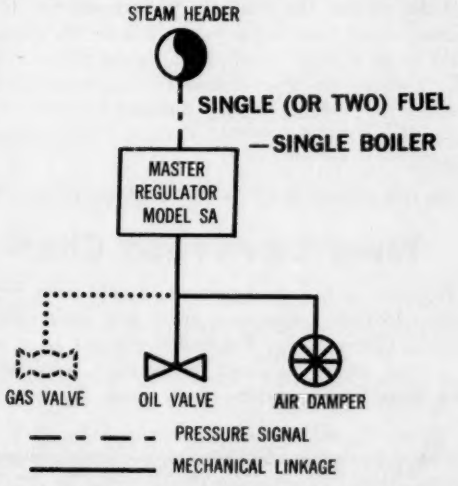


The Model A1011 can be used as a signal generator and monitoring device to provide shaped or compensated power distribution for amplifiers to drive high intensity acoustic test facilities . . . The basic A1011 system includes a random noise source, clipper, summing amplifier, spectral analyzer and sweep generator, and switching means . . . The output of the monitoring accelerometers can be visually displayed over the full frequency spectrum on a cathode ray tube. The operator adjusts compensator and filter control to obtain a display that conforms to the specified test. . . . (*From* 4-*page bulletin, Genisco Inc.,* 2233 *Federal Ave., Los Angeles* 64, *Calif.*)

FOR THIS LITERATURE CIRCLE 201 ON READER-SERVICE CARD

Combustion Control Systems

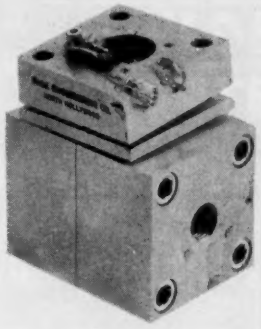
The prime objective of a combustion control system is to maintain the set steam pressure under varying load conditions. This must be done with the fuel and



air supplied in the proper ratio for most efficient combustion over the entire firing range . . . The choice between proportioning and metering is primarily determined by the point at which fuel consumption is sufficiently high for a slight increase in combustion efficiency to justify the additional capital expenditure . . . Several combustion control systems—proportioning and metering—are described . . . (*From* 32-*page Bulletin* 1001, "*Application Guide,*" *Reliance Instrument Div., Electro-Mech Corp., Norwood, N. J.*)

FOR THIS LITERATURE CIRCLE 202 ON READER-SERVICE CARD

Case History No. **3**



PACE

TRANSDUCERS CAN TAKE IT !

PACE Model P3D differential pressure transducers were used by a missile Auxiliary Power Unit manufacturer to measure Hydrazene flow rate in production testing. The instrument was mounted adjacent to a turbine when the rotor failed. In the resulting explosion, the transducer was struck by pieces of the rotor blade, knocked loose from its mounting and hurled 60 feet.

When rechecked at the factory, the transducer was found to be operative and within original specifications. With a new connector and mounting plate, it was as good as new.

PACE builds a complete line of rugged, reliable magnetic reluctance transducers, designed to withstand extreme pressure overloads and the abuse encountered in normal and abnormal applications.

Write today for detailed information and engineering assistance on these transducers, Pace Instrumentation Systems, and laboratory, production line and in-flight Thermocouple Reference Junctions.

PACE *engineering company*

13035 Saticoy Street — North Hollywood, California

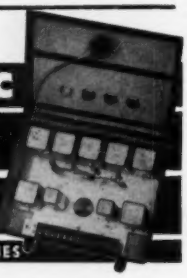
TRiangle 7-7139

CIRCLE 76 ON READER-SERVICE CARD

Synchro-Start

FULL AUTOMATIC ENGINE CONTROLS

FOR GASOLINE DIESEL & GAS ENGINES



Synchro-Start's new protective engine controls have been designed, for the starting and stopping of engines from remote pilot devices, such as pressure switches, float switches, power failure relays, etc., and are completely automatic in operation.

These dependable controls are encased in a steel, dust proof cabinet, and now feature enclosed PLUG-IN RELAYS as well as OVERLOAD BREAKERS. The plug-in relays simplify what little field maintenance that may have been required in older models, while the overload breakers eliminate the necessity of replacing fuses.

In designing this unit we have used the same high quality materials and workmanship that our customers have come to expect throughout Synchro-Start's 27 years of manufacturing engine controls.

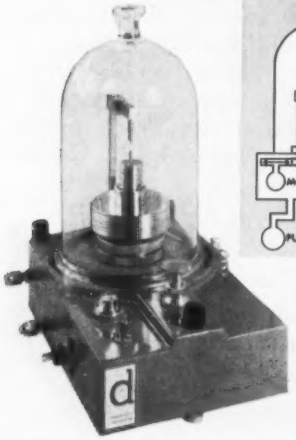
SYNCHRO-START PRODUCTS, INC.

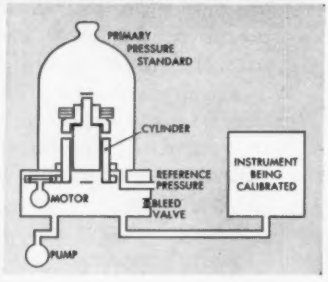
Since 1932

8151 NORTH RIDGEWAY AVENUE • SKOKIE, ILLINOIS

CIRCLE 77 ON READER-SERVICE CARD

NEW! PRIMARY PRESSURE STANDARD with Cyclic Bi-directional Rotation





Now you can calibrate any pressure measuring instrument from 0.2 psi absolute to 500.0 psi gauge with an accuracy of 0.015% of range!

- Exclusive cyclic bi-directional rotation of cylinder minimizes lift error
- Four pressure ranges
- Use any reference pressure from zero to one atmosphere absolute
- Self-contained pressure source provides pressure up to 15 psi

Write for Technical Bulletin 150

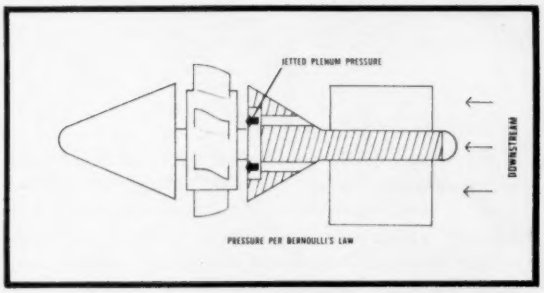
DYNAMETRICS CORPORATION

Northwest Industrial Park, Dept. 10, Burlington, Mass.

CIRCLE 78 ON READER-SERVICE CARD

Hydropoise Turbine Flowmeter

The accuracy, long life, and reliability of the FEC HYDROPOISE transducer is assured by the pressure feedback system which keeps the rotor in a balanced, free flowing position between the support and the cone. The upstream cone acts as a drag shield. The



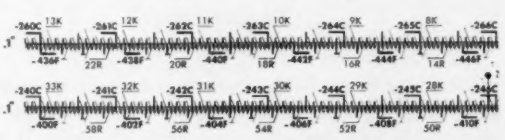
BALANCING EFFECT OF PRESSURE FEEDBACK SYSTEM

drag pressure ex[illegible] a force on the rotor blades in a downstream direction. The differential pressure due to an effective difference in cross-sectional area (Bernoulli's Law) exerts a force in the upstream direction. Balance between the upstream pressure and the downstream pressure is obtained as follows: A plenum relief, formed between the upstream end of the rotor and the downstream face of the support, tends to change size according to the *upstream* force on the rotor, and *downstream* force exerted on the rotor by plenum pressure. The smaller the plenum relief, the greater the pressure on the upstream side of the rotor and the greater the tendency to increase size of the plenum relief, reducing pressure, and so on. Thus, the rotor tends to stay balanced due to the pressure feedback between the downstream and upstream pressure systems . . . (*From* 4-*page Bulletin FEC*-101, *Francisco Engrg. Co., Inc.*, 23987 *Ventura Blvd., Calabasas, Calif.*)

FOR THIS LITERATURE CIRCLE 203 ON READER-SERVICE CARD

Temp Conversion Chart

New 8½″ x 11″ chart printed on both sides permits rapid, accurate conversion from any scale—Kelvin, Rankin, Centigrade or Fahrenheit—to any other scale. . . . First, locate the exact temperature, using whichever scale is appropriate, then, using the new scale

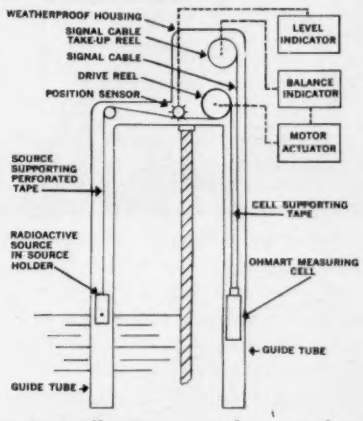


you want, read off the corresponding temperature at this point. Range is from absolute zero to 16,000°C. Accuracy of rulings is approximately 0.01° below 100°C, 0.02° up to 300°C, 0.05° up to 800°C, 0.2° up to 2000°C, 1° up to 6000°C and 5° up to 16000°C. . . . (*From Bulletin* 10605, *Rosemont Engineering Co.*, 4900 *W. 78th St., Minneapolis* 24, *Minn.*)

FOR THIS LITERATURE CIRCLE 204 ON READER-SERVICE CARD

Motor-Driven Level Gage

For a higher degree of accuracy over a wide range, the Ohmart Model MDL or MDLV motor driven level gage can be furnished . . . Referring to the schematic drawing, the source of gamma radiation and an Ohm-



art measuring cell are mounted on steel tapes that wrap around a motor driven drum. One of the tapes is equipped with perforations that engage the position sensor sprocket. As the drum rotates, the source and measuring cell are moved up and down together, and the position sensor rotates. The position sensor operates through a gear reduction mechanism to two potentiometers that give output voltages that are a function of the position of the source and cell. One potentiometer is set to indicate the full range in feet; the other is set to indicate inches within that range . . . A zero-suppression circuit is adjusted so that the meter on the balance indicator unit indicates zero when the level is at the midpoint of the measuring cell and source. As the level moves up, the balance indicator reads off-balance, and by means of the motor actuator, the source and cell move until the system returns to balance. The new level is then read on the level indicator . . . (*From 4-page Bulletin 106, Ohmart Corp., 2236 Bogen St., Cincinnati 22, Ohio.*)

FOR THIS LITERATURE CIRCLE 205 ON READER-SERVICE CARD

Static Power Conversion

Static power conversion equipment refers to any equipment which converts electrical power from one form to another without the use of moving parts such as rotors or vibrators. "Static" implies the use of semiconductors—and the exclusion of tubes. Typical conversions are: (1) dc to ac (in which case the unit is usually called an *inverter*), (2) ac of one frequency or phase to ac of another frequency or phase (in which case it is usually called a *converter*), (3) dc of one voltage to dc of another voltage (*converter or power supply*). (4) There are many other specialized cases in which power conversion equipment is used to provide power which is controlled so that it is "better" than the power available; for example, where the ac power available is not well regulated and it is desired to obtain power of very close regulation either for voltage or for frequency . . . (*From 20-page booklet, "Static Power Conversion Guide," Hamilton Standard, Div. United Aircraft Corp., Broad Brook, Conn.*)

FOR THIS LITERATURE CIRCLE 206 ON READER-SERVICE CARD

Select from over 3,500 different SOLENOID VALVES from VALCOR

Series SV-54 (3 way-4 way) general purpose solenoid valves for air, oil and water. Rugged construction, yet inexpensive. Multi-million cycle life. Pressure ratings up to 150 psi. Nylon seat outlasts steel. Infinite varieties available . . . lists as low as $10.75.

Series SV-61 (2 way) Nylon body valve is ideal for general purpose and OEM installations where millions of operating cycles are vital. Nylon seat and port threads outlast steel, yet cost less. Non-corrosive, shock-resistant, proof-pressure.

Series SV-5100 Specifically designed to handle the most corrosive media in industry. Manufactured in Teflon, PVC and Nylon varieties. Diaphragm construction prevents media contact with any metal. Available in direct-acting or piloted models.

VALCOR SOLENOID VALVES

FREE... new 16 page brochure —lists over 500 corrosive media—coded for correct valve selection.

For complete information on these or other models, write or call:

VALCOR ENGINEERING CORP.
5366 Carnegie Ave., Kenilworth, N. J.
CHestnut 5-1665

CIRCLE 79 ON READER-SERVICE CARD

Now NO-BLADE Stripping makes wire damage impossible!

New IDEAL

THERMO-STRIP

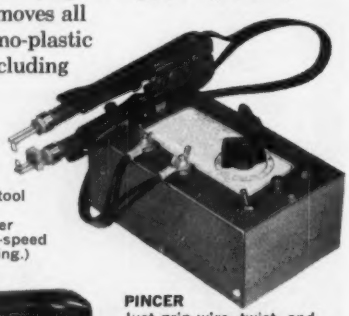
FOR PLASTIC INSULATION

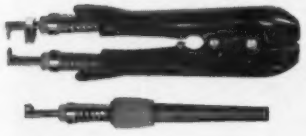
- For use where absolutely no wire damage is permissible
- Can operate continuously—no warm-up delay
- Infinitely variable heat control—prolongs element life—reduces fumes

Especially designed to meet zero-defect requirements in assembly of missiles components, aircraft, computers and other precision electronic systems and instruments, the new Ideal Thermo-Strip Hot Wire Stripper completely eliminates the possibility of nicks, breaking or disturbing of strands in even the finest wires. *Not* just a converted soldering iron, it is all new, light-weight, easy-to-use, and safely removes all types of thermo-plastic insulation, including Teflon.

COMPLETE . . . READY TO USE . . .

Includes 50-watt transformer and tool of your choice. (Shown with Pincer mounted for high-speed production stripping.)





PINCER
Just grip wire, twist, and pull off insulation slug with heating elements.

SINGLE LOOP
For "probing" into miniature or crowded assemblies. Just put wire end in V-notch of electrode.

Elements may be formed for any wire size or particular service.

Sold Through America's Leading Distributors
IN CANADA: IRVING SMITH, Ltd., Montreal

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☐ Have your representative arrange a trial for me. ☐ Send data only now.

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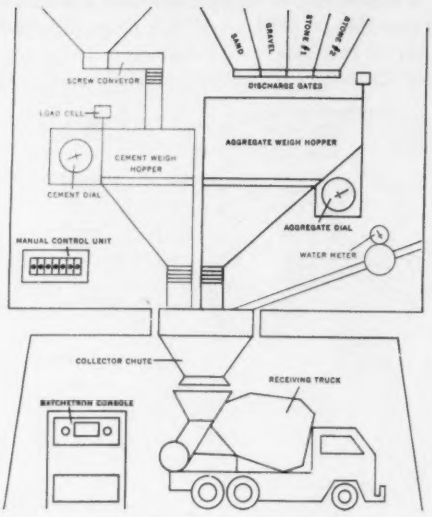
CIRCLE 80 ON READER-SERVICE CARD

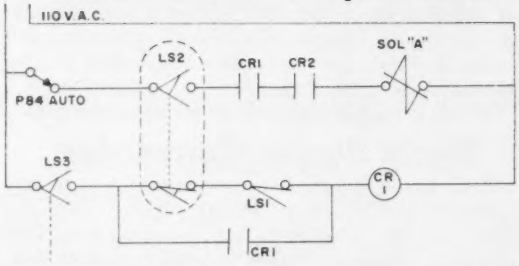
Automatic Batching



The new DPB Series 600 Batchetron . . . is especially designed for concrete and asphalt proportioning. It . . . weighs out pre-set amounts of any material that can be pushed, poured or dropped into weight hoppers . . . does it in a pre-selected sequence that can be repeated automatically. Interlocks prevent incorrect sequence and halt operation if something goes wrong. Control panel meters allow the operator to adjust for hopper tare weights, while pilot lights indicate batching startup, sequence and finish . . . (*From 4-page brochure, Electronics Div., Fairbanks, Morse & Co., 505 Oakland Ave., West Hartford, Conn.*)

FOR THIS LITERATURE CIRCLE 207 ON READER-SERVICE CARD

Double-Break Snap-Action



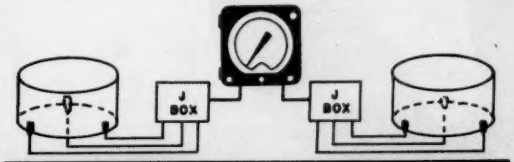
Multiple break, or double break contacts effectively increase electrical capacity and electrical life of a switch. Arc energy is distributed over more than one location. The heat is, therefore, dissipated at two places, minimizing the possibility of contact weld . . . In any multiple break switch the action must be simultaneous. If it is not, the advantage is lost, since the last contact to make or the first contact to break would carry the full load.

With the double break contact arrangement we derive a two circuit feature. The figure illustrates this advantage as applied to isolation of control circuits . . . (*From 32-page catalog featuring 4-pages of basic terminology, Licon Div., Illinois Tool Works, 6606 W. Dakin, Chicago 34, Ill.*)

FOR THIS LITERATURE CIRCLE 208 ON READER-SERVICE CARD

Indicating Controllers

The SR-4 Type 110 Pointer Indicator & Indicating Controller is a compact, versatile instrument developed primarily for use in measuring and control sys-



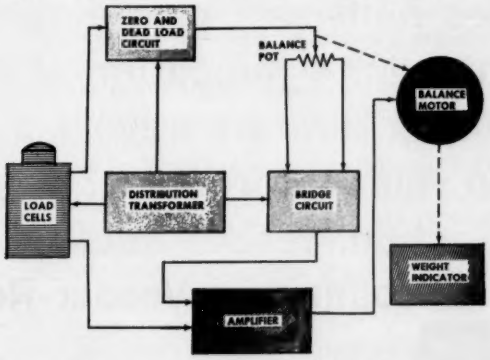
Two independent systems, employing 2, 3 or 4 load cells each, with totalized outputs separately indicated by a single instrument.

tems employing resistance strain gage transducers. It is well-suited to a wide variety of industrial applications, including weight and load measuring systems, pressure systems, torque and horsepower measuring systems, etc. . . . An automatic null-balance type instrument, it utilizes a servo-driven slide wire to balance an internal bridge circuit. Standard models provide overall system accuracies of up to $\pm\frac{1}{2}\%$, and are available for use with both AC and DC transducer systems . . . Where two independent transducers are employed, a dual-input DC Instrument may be used to indicate both outputs individually. A front-panel switch is provided on dual-input models to select the desired input channel . . . (*From 6-page Bulletin* 4411, *Baldwin-Lima-Hamilton, Electronics & Instrumentation Div., Waltham* 54, *Mass.*)

FOR THIS LITERATURE CIRCLE 209 ON READER-SERVICE CARD

Electronic Weighing

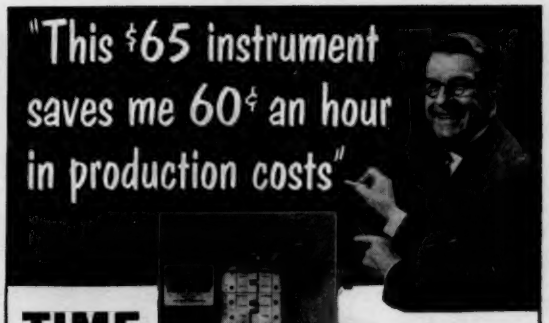
The Ametron Electronic Scale is comprised of 2 basic units: 1) load cell unit, 2) servo system data presentation device. The Load Cell consists of a variable resistance strain gage bonded by bakelite cement to an accurately machined load member. When a weight is applied to the load cell, a change in the strain



gage resistance introduces a voltage change, . . . passes it through an amplifier which, in turn, operates a two-phase motor. The motor changes a variable resistor to compensate for the voltage difference of the bridge circuit. It also positions a step cam printer locating the correct typewheel positions for a weight recording. When "zero" voltage exists in the bridge circuit, the motor stops . . . (*From 6-page brochure, Streeter-Amet Co., Grayslake, Ill.*)

FOR THIS LITERATURE CIRCLE 210 ON READER-SERVICE CARD

"This $65 instrument saves me 60¢ an hour in production costs"



TIME RECORDER + TOTALIZER

what TRT is — An instrument that automatically records "on-off" time of **any machine or process.** Information is marked on a continuous, time-indexed tape. Marking stylus is electrically actuated. Tapes run 4 months.

what TRT does — Shows on tape **exactly when** "down-time" occurs, how long it lasts. Access window enables operator to write reason for stoppage. Visual counter totals **actual productive time.**

how TRT saves — TRT data-on-tape gives accurate, single-source basis for **cost-cutting** in plant or office: time study, production control, preventive maintenance, locating bottlenecks. Write for free Brochure IR-4

standard INSTRUMENT CORPORATION
657 BROADWAY, NEW YORK 12, N. Y.

CIRCLE 81 ON READER-SERVICE CARD

INCREASE RECORDER VERSATILITY

MULTI-SPEED CHART DRIVE FOR STRIP CHART RECORDERS

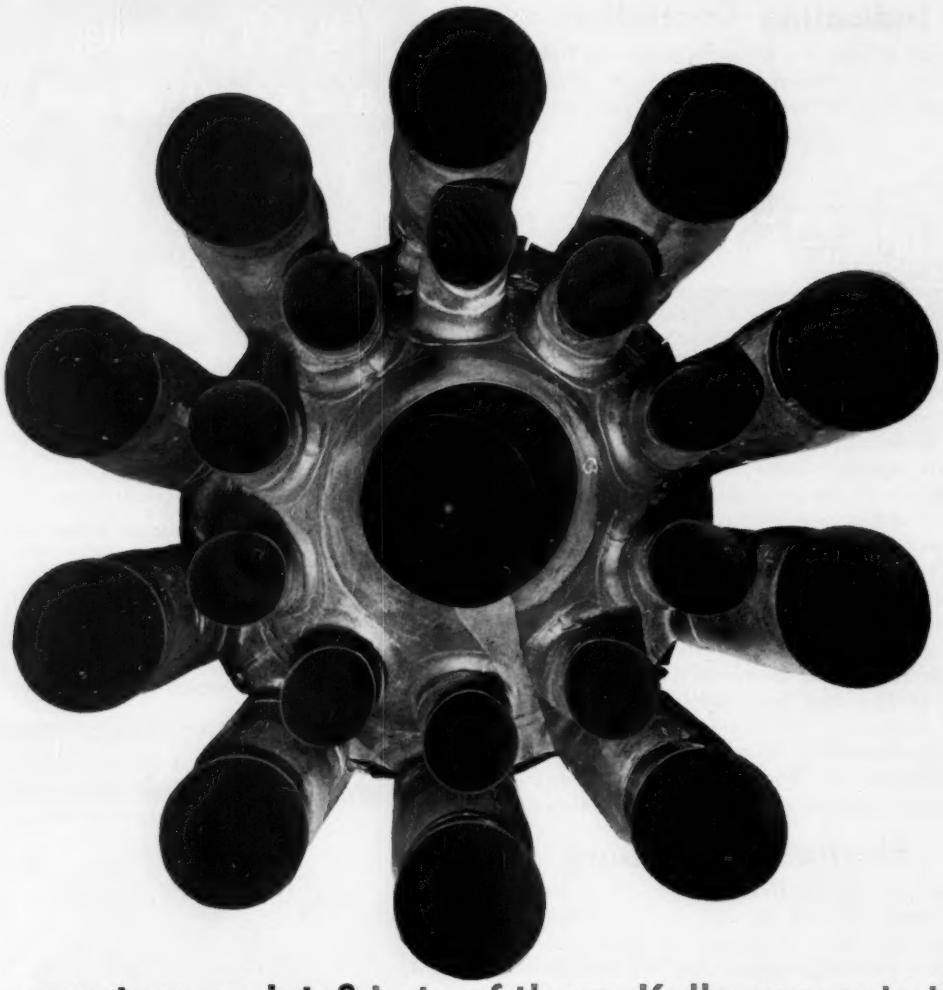
BUILT BY — HONEYWELL — LEEDS & NORTHRUP — BRISTOL — WHEELCO — GENERAL ELECTRIC (EASILY FIELD MOUNTED)

Matches Chart Speed to Test Requirements • Quick dial selection of eight speeds • Improves resolution and readability of plotted curves • Provides greater total chart speed range • Saves chart paper • Saves valuable time.

CHART DRIVES • SPEED REDUCTORS • INSTRUMENT DRIVE SYSTEMS

INSCO COMPANY
DIVISION OF BARRY WRIGHT CORP.
GROTON, MASSACHUSETTS

CIRCLE 82 ON READER-SERVICE CARD



what!—counters on jets? Lots of them. Kollsman puts them there. And Veeder-Root supplies Kollsman, providing jet pilots with direct read-out—immediate indication of the vital data necessary for controlling aircraft travelling at jet speeds. Can Veeder-Root help your performance? Better find out. Write to Instrument Section, Veeder-Root Incorporated, Hartford 2, Connecticut. **count on . . . Veeder-Root**

KOLLSMAN INSTRUMENT CORP.

Modern thrustmeter—one of many special instruments which uses Veeder-Root counting ingenuity—shows pilots the power conditions necessary for safe take-off.

CIRCLE 83 ON READER-SERVICE CARD

1961 IRE Show

EDITORIAL

THE 1961 International Convention of the Institute of Radio Engineers was held during the week of March 20 in New York City. The 54 technical sessions covered everything from medical to military electronics, from practical applications to advanced theory.

The major emphasis was on advanced components for military systems, including traveling-wave and backward-wave tubes, tunnel diodes, parametric amplifiers, thin-film memories, miniaturized "dot-sized" components, etc. But interest is growing rapidly in three areas—medical, logic circuitry, and precision measurements.

The exciting field of circuit and system development via logic modules is attracting great attention (readers of I&CS have had a basic series on this subject for more than one year). Logic modules were displayed at IRE by Radiation, Inc., Epsco Components, Packard-Bell Computer, Digital Equipment Corp., Di/An Controls, Engineered Electronics Co. (EECO), Fairchild Semiconductor (new Micrologic family), Computer Control Co., C&K Components, AMP (AMP-MAD elements), Data Systems Div. of Harman-Kardon, and C. P. Clare & Co. These elements use the techniques of gates, transistors, NOR circuitry, cores, and combinations for their logical implementation of circuits and situations. Of interest is the new *Clareed Relays* of C. P. Clare & Co., in which the logic is performed in interacting flux fields. (This will be reported in detail in our symbolic-logic series.)

In the area of *precision measurements*, a new line of potentiometer pressure transducers was unveiled by DeJur-Amsco Electronics Div. Fairchild also displayed a new potentiometric pressure transducer.

Packard-Bell unveiled a potentiometric amplifier with bandwidth to 100 kc, gain to 1000, stability of 0.01%, 1000-megohm input impedance.

North Atlantic unveiled precision phase-angle and ratio instruments.

Counters are becoming even more versatile. Beckman displayed a reversing counter (Model 3300) that counts up, or down, adds two counts, subtracts them, monitors their deviation, etc.

Calibration consoles were displayed by Sensitive Research, Julie Research, Radio Frequency Labs., and others.

Other precision measurements instruments of interest included a complete new line by Simpson, a universal impedance bridge by John Fluke, an electronic Wheatstone bridge (electronic null detector for Wheatstone Bridges) by Millivac-Cohu; a standard frequency meter by Measurements, a ratio bridge by Gertsch for phase measurement (accuracy in quadrature is 0.1%).

There was much interest in timing and frequency standards also, including the crystal-controlled standards of Rhode & Schwarz, the rubidium frequency standard of STL, the Atomichron frequency standard of The National Co., the tuning-fork standards of Hathaway.

Many new recorders were unveiled including direct-writing optical oscillographs with response to 8000 cps.

In the medical area, the IRE selected a paper in the field of medical electronics for its annual "best paper of the year" award (and the same week saw the emergence of the nation's first national-coverage trade journal in the field of bio-medical electronics—*MEDICAL ELECTRONICS NEWS*, with a first-copy circulation of 35,000, published by *Instruments Publishing Co.*) The IRE paper that won the W. R. G. Baker Award of the IRE for the year's most outstanding technical paper was "Respiratory Control of Heart Rate: Laws Derived from Analog Computer Simulation," by Manfred Clynes, President of Mnemotron Corp., Spring Valley, N. Y.

The same firm exhibited "telephone transmission of electrocardiograms" via SONLINK PFM Sound Data Converter—an instrument that permits any person with a cardiograph to transmit the signal over any telephone to a receiver which reproduces the data into its original analog form. This permits the cardiograph to be analyzed immediately at the remote station, simply by dialing a number on a telephone. Of course, this system permits any 0-100 cps data to be so telemetered and received. The same firm also offers the CAT Computer of Average Transients designed to analyze brain wave signals with signal-to-noise ratios of 1:30 or worse. An electronic obstacle detector for the blind also was reported by Biophysical Electronics.

Today the commercial market for medical electronic equipment is small—in the order of $200,000,000, mostly X-ray devices, a microscopic figure compared to other areas of electronics. But it is significant that the new publication—*MEDICAL ELECTRONICS NEWS*—is being published by The Instruments Publishing Company which, 34 years ago, brought out the world's first trade journal in industrial measurement and control—the magazine *INSTRUMENTS* (now known as *INSTRUMENTS & CONTROL SYSTEMS*). The market for industrial instruments thirty years ago was even smaller than the present medical electronic market—but it grew to become the multi-billion-dollar automation industry in which the publication *INSTRUMENTS & CONTROL SYSTEMS* is the acknowledged pioneer and leader. History repeats, at an accelerating pace.

The electronics industry has experienced five major periods—the radio era, the radar era, the television era, the industrial era, the missile era. It is about to enter its sixth and most important era—the MEDICAL ERA.

THE D-P FLOWMETER EQUATION

PAUL ODOM
Pratt & Whitney Aircraft

The derivation of the basic constant-area differential-pressure flowmeter equation for venturis, nozzles, orifices, and dall flow tubes.

TERMINOLOGY

A—Area, ft^2
C—Discharge coefficient, $f_1(N_r)$, $f_2(\beta)$
D—Diameter, ft
d—Diameter, inches
E—Energy, ft-lbs/lb of fluid flowing
g—Acceleration of gravity, 32.2 ft/sec^2
H—Differential pressure, ft of flowing fluid
h—Differential pressure, inches of flowing fluid
J—Conversion factor, 778 ft-lbs/Btu
k—Specific heat ratio
M—Velocity-of-approach factor, $1/\sqrt{1-\beta^4}$
P—Static pressure, lbs/ft^2
p—Static pressure, lbs/in^2
Q—Volumetric flow rate, ft^3/sec
q—Heat transfer rate, Btu's/lb of fluid flowing
T—Temperature, °Rankine (460 + °F)
u—Internal energy, Btu's/lb of fluid flowing
V—Velocity, ft/sec
v—Specific volume, $ft^3/lb = 1/\omega$
W—Gravimetric flow rate, lbs/sec
w—Work, ft-lbs/lb of fluid flowing
Y—Expansion factor, $f_3(p_2/p_1)$, f_3 (k), f_3 (β)
Z—Potential energy, ft of elevation

Subscripts:
1—Conditions upstream of throat (line)
2—Conditions at throat
s—Standard conditions
m—Manometer
f—Flowing fluid
i—System inlet (also subscript 1)
o—System outlet (also subscript 2)

Greek symbols:
β—Diameter ratio = Throat dia ÷ Pipe ID = d_2/d_1
μ—Dynamic viscosity, slugs/ft-sec
ω—Specific weight, $lbs/ft^3 = 1/v$
ρ—Mass density, $slugs/ft^3$

Abbreviations:
ASME—American Society of Mechanical Engineers
AGA—American Gas Association
VDI—Verein Deutscher Ingenieure (Society of German Engineers)

FLOWMETER ENGINEERING, as practiced by the ASME, AGA, and VDI codes, is based on the principle of the conservation of energy. This principle is the basis of the first law of thermodynamics. A statement of this law is that *"Heat and work are mutually convertible, but since energy can neither be created nor destroyed, the total energy associated with an energy conversion remains constant."* This principle, when applied to a steady flow process, is simply an accounting of all the energy terms involved in the process.

The Energy Equation

This relation states that all the energy in a fluid entering a system (E_1) plus the net heat added to the system (Jq) equals all the energy in the fluid leaving the system (E_o) plus the net work performed by the system (w). That is:

$$E_1 + Jq = E_o + w \qquad (1)$$

The work term (w) may be separated into two parts: (1) The work required to move the fluid across the system (w_f), and (2) all other forms of work (Σw).

$$E_1 + Jq = E_o + w_f + \Sigma w \qquad (2)$$

The work required to move the fluid across the system is derived as follows: arbitrarily select entrance and exit planes for the system. Each pound of fluid that enters (or leaves) the system consists of a plug of fluid of cross-sectional area A and length L. Since work is the product of force and distance, the work done in moving a 1-pound plug of fluid across the boundary plane is equal to the product of the force on the plug (PxA) and the plug length L. This results in the following expression for the net "flow work":

$$w_f = (PAL)_o - (PAL)_1 \qquad (3)$$

The product of A and L (area times length) is a volume. As we are considering the work associated with each pound of fluid, the product AL is the specific volume v, and

$$w_f = P_o v_o - P_i v_1 \qquad (4)$$

Substituting for w_f in equation (2):

$$E_1 + Jq = E_o + P_o v_o - P_i v_1 + \Sigma w \qquad (5)$$

The energy term (E) can be separated into 3 parts: (1) *Potential energy* (Z) is the result of a difference in height between the system entrance and exit; it is numerically and dimensionally equal to the measured difference in elevation. (2) *Internal energy* (u) is the energy stored in the molecules of the fluid and consists of molecular kinetic energy of translation, molecular rotational energy, molecular vibrational energy, and potential energy relating to molecular binding forces. (3) *Kinetic energy* ($V^2/2g$) is the energy the fluid posesses by virtue of its velocity. Substituting for E in equation 5:

$$Z_i + u_i + V_i^2/2g + Jq = Z_o + u_o + V_o^2/2g + P_ov_o - P_iv_i + \Sigma w \quad (6)$$

$$Z_i + u_i + V_i^2/2g + P_iv_i + Jq = Z_o + u_o + V_o^2/2g + P_ov_o + \Sigma w \quad (6a)$$

This is the general energy equation for the steady flow of a fluid through any machine or device.

The D-P Flowmeter Equation

In adapting the general energy equation to a differential-pressure flowmeter, the system inlet becomes the section of pipe immediately upstream of the meter constriction (or throat), and the system outlet becomes the meter throat (Fig. 1). Substituting subscript 1 for i, and 2 for o, and making the following assumptions:

1. The flowmeter is horizontal so the change in potential energy between the pressure taps is zero. If the flowmeter is inclined or vertical the vertical distance between the pressure taps (expressed in feet of fluid flowing at flowing conditions) must be added to or subtracted from the differential pressure. When the flowing fluid is a gas this error is negligible.
2. The heat transfer q is negligible.
3. The work term Σw is zero. (In a flowmeter energy conversion the only applicable work term is w_f)
4. The change in internal energy is zero. This assumption is not true because of friction, but the discrepancy is accounted for later by the introduction of the discharge coefficient "C."

Owing to these assumptions, equation 6a becomes:

$$P_1v_1 + V_1^2/2g = P_2v_2 + V_2^2/2g \quad (7)$$

$$2g(P_1v_1 - P_2v_2) = V_2^2 - V_1^2 \quad (7a)$$

V_1 can be expressed in terms of V_2 by use of the continuity equation:

$$Q = A_1V_1 = A_2V_2 \quad (8)$$

$$V_1 = V_2(A_2/A_1) = V_2(d_2/d_1)^2 \quad (8a)$$

Substituting for V_1 in equation 7a:

$$2g(P_1v_1 - P_2v_2) = V_2^2 - V_2^2(d_2/d_1)^4 \quad (9)$$

$$2g(P_1v_1 - P_2v_2) = V_2^2[1 - (d_2/d_1)^4] \quad (9a)$$

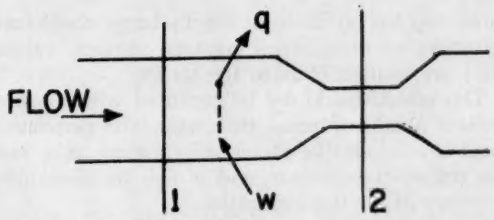


FIG. 1. FLOW SECTION with constriction for producing a differential pressure.

Arranging V_2 as the dependent variable:

$$V_2 = \sqrt{\frac{2g\,(P_1v_1 - P_2v_2)}{[1 - (d_2/d_1)^4]}}\ \text{, ft/sec} \quad (9b)$$

Substituting for V_2 in the continuity equation: ($Q = A_2V_2$):

$$Q = A_2\sqrt{\frac{2g\,(P_1v_1 - P_2v_2)}{[1 - (d_2/d_1)^4]}}\ \text{, ft}^3\text{/sec} \quad (10)$$

Discharge Coefficient

Equations 9b & 10 are theoretically correct and if idealized flow conditions (isentropic energy conversion) could be realized, would be correct. However, they are in error because of the assumption that the internal energy change was zero. To correct this, the *discharge coefficient* C is introduced. It is defined as being the ratio of the true flow rate (as determined by calibration) to the theoretical flow rate (as determined by equation 10).

Up to this point the equations have been independent of the geometry of the flowmeter.* The discharge coefficient takes this into account since, for a given Reynolds number, it varies with meter design. In the case of orifices it also varies with diameter ratio (β). This is because the discharge coefficients for orifices include a "contraction coefficient." The contraction coefficient is the ratio of minimum jet area (vena contracta) to orifice opening area, and is the result of the stream cross-sectional area continuing to decrease after passing through the orifice.

The discharge coefficient depends on the shape of the meter between the differential-pressure taps only. The meter configuration downstream of the

*Gentile flow tubes cannot be considered in this discussion because they do not present a differential pressure that is any known function of velocity. Their differential pressure is the difference between inlet total (or stagnation) pressure and a downstream pressure that is less than stream static. The taps are arranged in pylons (or recesses) so that the upstream tap is facing squarely into the stream and the downstream tap is facing directly downstream. This results in a greater differential pressure (for the same flow and throat size) than can be obtained from static taps placed at upstream and throat conditions, but means that each meter must be calibrated for the particular conditions over which it will be used. In other words, the flow rate cannot be calculated from theoretical considerations, and no coefficient exists to establish dynamic similarity.

throat tap has no effect on the discharge coefficient, assuming no disturbance creators (pumps, valves, etc.) are located close to the throat.

This effect should not be confused with the *permanent head loss* across the meter. The permanent head loss across the meter is expressed as a % of the differential-pressure and is due to incomplete recovery of the static pressure.

Inserting C in equation (10):

$$Q = CA_2 \sqrt{\frac{2g\ (P_1v_1 - P_2v_2)}{[1 - (d_2/d_1)^4]}},\ ft^3/sec \qquad (11)$$

Velocity-of-Approach Factor

The factor $1/\sqrt{1 - (d_2/d_1)^4}$ is called the *velocity-of-approach* factor and is designated by M. It modifies the flow equation for the effect of upstream velocity. From inspection it is seen that as the throat diameter (d_2) becomes small compared to the upstream diameter (d_1), M approaches 1. This is intuitively reasonable since the upstream velocity, relative to the throat velocity, approaches zero as the throat velocity increases due to a decrease in throat diameter. In the familiar relation $V = \sqrt{2gH}$ it is assumed that the upstream velocity is zero. If not, the relation becomes $V = M\sqrt{2gH}$.

Inserting M in equation (11):

$$Q = MCA_2 \sqrt{2g\ (P_1v_1 - P_2v_2)},\ ft^3/sec \qquad (12)$$

The product MC is sometimes used as a single "Flow Coefficient" and called K.

Expansion Factor

The assumption is now made that $v_2 = v_1$, and the coefficient Y is introduced and defined as being a correction factor for any error introduced in making this assumption:

$$Q = YMCA_2 \sqrt{2gv_1\ (P_1 - P_2)},\ ft^3/sec \qquad (13)$$

Since $v = 1/\omega$:

$$Q = YMCA_2 \sqrt{2g\ (\Delta P/\omega_1)},\ ft^3/sec \qquad (13a)$$

The factor Y, as introduced into equation (13), is called the *expansion factor*. It is a function of the specific heat ratio k, the diameter ratio β, and the pressure ratio P_2/P_1 (or $[P_1 - \Delta P]/P_1$). Thus for a given flowmeter and gas, Y is a function only of the pressure ratio. Tables and curves of expansion factors can be found in published literature such as the ASME *Fluid Meters, Their Theory and Application*. For venturis and nozzles the values of Y are theoretical; for orifices they are empirical.

The Working Form of The Equation

A fundamental relation of fluid statics is $\Delta P = H\omega$, where H is the height of a column of fluid of specific weight ω supported by a difference in pressure ΔP. Replacing $(\Delta P/\omega_1)$ in equation (13a) by H:

$$Q = YMCA_2 \sqrt{2gH},\ ft^3/sec \qquad (14)$$

Since ω_1 is the specific weight of the flowing fluid, H is expressed in feet of flowing fluid (at flowing pressure and temperature).

This is the working form of the flow equation and is the most versatile and easily remembered form. Inspection of equation (14) reveals that, for a given flowmeter and line fluid:

a. M, A_2, and $\sqrt{2g}$ become a single constant.
b. Y is a function of the pressure ratio only. For an incompressible fluid the assumption that $v_2 = v_1$ is valid and $Y = 1$.
c. C is a function of Reynolds number, N_r. The Reynolds number is sometimes based on throat conditions and sometimes based on pipe (or line) conditions. If the Reynolds number base is not identified it is assumed to be the throat Reynolds number.
d. H is the height of a column of the flowing fluid supported by the difference in pressure between the points where the fluid enters and leaves (the flowmeter taps). If the flowing fluid is a compressible gas, the manometer fluid height must be converted to an equivalent height of gas at the pressure and temperature of the gas in the line.

It should be realized that, for compressible flow, Q (as found from the above equations) represents volumetric units at *flowing conditions* and not standard volumetric units.

When it is desired to compute flow in terms of standard volumetric units the ideal gas law is used as follows:

$$P_sQ_s/T_s = P_1Q_1/T_1 \qquad (15)$$

where Q_1 is the flow as found from equation (14) and P_1, T_1 are the pressure and temperature associated with ω_1.

$$Q_s = YMCA_2 \sqrt{2gH}\ (P_1/T_1)(T_s/P_s),\ scfs \qquad (16)$$

scfs = standard cubic feet per second based on a standard pressure P_s and a standard temperature T_s.

When it is desired to compute flow in *gravimetric* units, equation (14) is multiplied by ω_1 and equation (16) by ω_s:

$$W = YMCA_2\ \omega_1 \sqrt{2gH},\ lbs/sec \qquad (17)$$

$$W = YMCA_2\ \omega_s \sqrt{2gH}\ (P_1/T_1)(T_s/P_s),\ lbs/sec \qquad (17a)$$

Manometer Relations

The differential-head H frequently is indicated on a manometer connected between the flowmeter inlet and throat taps. As the manometer fluid must be different from the flowing fluid, it is necessary to convert the manometer indication to an equivalent height of flowing fluid. The conversion formulas are derived as follows (Fig. 2):

$$P_1 + (b + H_m)\omega_f + (a - b - H_m)\omega_m = P_2 + b\omega_f + (a - b)\omega_m \qquad (18)$$

Rearranging:

$$P_1 - P_2 = \Delta P = H_m(\omega_m - \omega_f) \qquad (18a)$$

Remembering that $\Delta P = H\omega_1 = H\omega_f$:

$$H\omega_f = H_m(\omega_m - \omega_f) \qquad (19)$$

$$H = H_m\left(\frac{\omega_m}{\omega_f} - 1\right) \qquad (19a)$$

The specific weights used are at the temperatures of the respective fluids. If the temperatures of the flowing and manometer fluids are not too far apart, and if both fluids are liquids, the specific gravities may be used instead:

$$H = H_m\left(\frac{SG_m}{SG_f} - 1\right) \qquad (20)$$

Reynolds-Number Calculations

The basic Reynolds-number equation is:

$$N_r = \rho VD/\mu \qquad (21)$$

where ρ is mass density in slugs/ft^3 and μ is dynamic viscosity in slugs/ft-sec (V and D are as before). Since $\rho = \omega/g$, equation (21) may be written:

$$N_r = \omega VD/g\mu \qquad (21a)$$

To compute a pipe Reynolds number, the characteristic velocity is taken as the velocity in the pipe upstream of the throat (station 1 in Fig. 1), and the characteristic dimension D is taken as the pipe ID. As the relation $V = M\sqrt{2gH}$ gives the velocity at the throat, the upstream velocity must be found from $V_1 = Q/A_1$ or $V_1 = W/A_1\omega_1$:

$$N_r = \omega_1 Q D_1/A_1 g \mu = 4\,\omega_1 Q/\pi D_1 g\mu \qquad (22)$$

$$N_r = \omega_1 WD_1/A_1\omega_1 g\mu = 4W/\pi D_1 g\mu \qquad (22a)$$

It is seen that the computation of a pipe Reynolds number involves an iteration process when the Reynolds number is being computed to find a flow rate. As the only reason for computing a Reynolds number in this case is to find the discharge coefficient, and as the discharge coefficient can be approximated within a few % for a given meter type and β ratio by inspecting the tables or curves, a calculation of Q using a first approximation of the discharge coefficient is sufficiently accurate for all but the most precise applications.

To compute a throat Reynolds number, the characteristic velocity is taken as the velocity at the throat, and the characteristic dimension is taken as the throat diameter. As the throat velocity is found from $V = M\sqrt{2gH}$:

$$N_r = \omega_2 M \sqrt{2gH}\left(D_2/g\mu\right) \qquad (23)$$

As a relatively large change in Reynolds number produces a small change in discharge coefficient, negligible error is introduced by letting $\omega_2 = \omega_1$, and M= 1 in throat Reynolds number calculations:

$$N_r = \omega_1 \sqrt{2gH}\left(D_2/g\mu\right) \qquad (24)$$

It is usually convenient to leave g out of a constant grouping because many curves of viscosity are plotted with $g\mu$ as the ordinate.

Flowmeter Specification Sheet

A specification sheet for d-p flowmeters has been prepared. It includes space for:

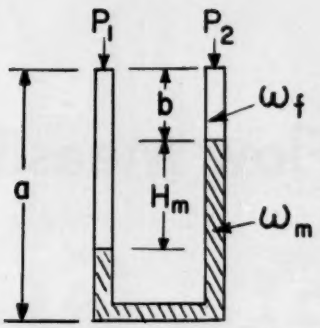


FIG. 2. MANOMETER used to indicate a differential pressure.

Meter type
Meter fluid
Range
Operating conditions—pressure, density, temperature, viscosity
Maximum pressure
Maximum temperature
Throat diameter
Head loss not to exceed —% of differential head
Accuracy
Calibration Required
Line Size
Connections
Materials

A reproducible plot of Flow Coefficient K vs pipe Reynolds Number shall be supplied with meter. These quantities shall be as defined by the ASME publication FLUID METERS, THEIR THEORY AND APPLICATION, Fifth edition. When calibration is required, Vendor shall supply copies of all data used to establish K vs pipe Reynolds no. curve together with a sketch of the calibration setup showing upstream and downstream pipe lengths and sizes and location of all pressure taps.

PAUL ODOM, 33, has a BS in Mechanical Engineering from Purdue University. Since 1956 he has been instrumentation engineer with Pratt & Whitney Aircraft at the Connecticut Aircraft Nuclear Engine Laboratory facility of the U. S. Air Force and AEC. From 1953-1955 he was instrumentation engineer with Pratt & Whitney Aircraft's jet engine development programs. He studied at Purdue University, 1950-1953, and Indiana University, 1948-1949.

Flow Measurement in Rocketry

Extremes of flow rate, temperature and pressure demand special instrumentation for missiles and rockets. Here is the part that flow measurement played in the Atlas program.

EVOLUTION of the Atlas Intercontinental Ballistic Missile from a concept to America's first operational ICBM resulted from a tremendously complex test program. The propulsion system, the hydraulic system (which actuates the controls), the guidance, and the ground support equipment progressed through a long series of development tests.

Flow measurement played an important role in the test program and called for the use of techniques, hardware and accuracies never before applied.

Many different flowing media had to be metered under a wide range of temperatures and pressures. The media included fuel oil, helium gas, liquid oxygen, liquid nitrogen, and gaseous nitrogen. The flow conditions included temperatures from —320° F to 400°F; pressure to 3,000 psi; flow rates from ¼ lbs/sec gas media, to 5,000 gpm liquid.

Flow Measurements in Engine Performance

The instrument engineers of the rocket engine manufacturer tackled the job of providing suitable flowmeters for testing the first Atlas prototype engine at the Propulsion Field Laboratory.

The combined flowrate (pounds/sec) of the two liquid propellants (fuel and oxidizer), divided into the total thrust in pounds developed by the engine, is called the *specific impulse*, and is expressed in seconds. The larger this number, the more efficient the engine. Specific impulses around 300 seconds (300 pounds of thrust for each lb/sec of propellant burned) are considered good.

Concurrent with the engine test program, a parallel component test program was conducted by both engine-builder and subcontractors supplying valves, ducting, etc. All these components also required flow testing.

The rocket-engine propulsion system must be thoroughly proved on the ground. This is done through a *static test program*, sometimes called "captive" or "tiedown" tests. In a static test program, flow measurements include (1) propellant flow (fuel and oxidizer), (2) gas flow to the turbopumps (as determined by measuring the liquids fed to the gas generator), and (3) pressurizing gas fed to the propellant tanks.

Comparisons of Flow Techniques

The choice of flow measuring technique was largely influenced by the following factors (in approximate order of importance)—(1) accuracy or precision, (2) reliability, (3) weight, (4) pressure loss caused by instrument, (5) availability, (6) cost.

Available hardware in the late 40's and early 50's was limited to familiar flowmeter types—orifice, nozzle, venturi, pitot and rotameter.

Early disappointment with orifice-metering led to investigation of newer techniques. A device that gave immediate promise was the *turbine-type flowmeter*, a transducer consisting of a freely-revolving bladed rotor which is driven by the fluid and rotates at a speed nominally proportional to the velocity of the fluid stream passing through it. The rotational speed (rpm) of the rotor represents fluid velocity (flowrate). In the early days of the test program, rotor speed was sensed mechanically by a gear-train driven by the rotor. Today, electrical sensing of rotor speed is used (Fig. 1).

Today's turbine flowmeters are made in both a screw-end and flange-end style, the latter for larger pipe sizes. The Instrument Society of America is developing standard end-to-end dimensions as well as standard terms and definitions for this type of flowmeter (RP31.1).

Calibration of Flowmeters

The most desirable method of calibrating a flow-measuring device is by use of a secondary standard, such as a *volume-calibrated tank*, certified by the National Bureau of Standards.

Another type of secondary standard is a *calibrated orifice run*. This method, although not as accurate as the volumetric method, is more practical. The flow unit to be calibrated, with all its

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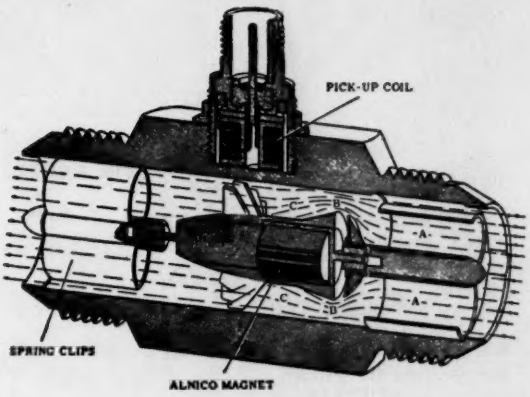


FIG. 1. **TURBINE** meter.

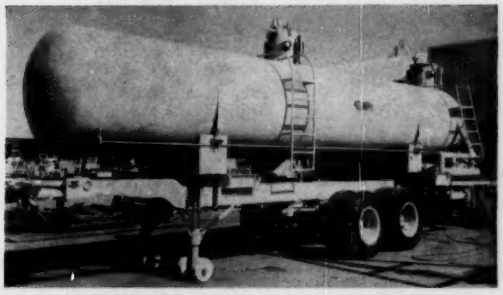


FIG. 2. **PROVER TANK** for volumetric calibration.

associated piping and sensing elements, is assembled in a configuration closely resembling that used during an actual metering run. For example, if certain valves will be used in the metering run, these items should be installed in the calibration set-up. This is also true of pressure-sensing lines. In addition to duplicating actual metering runs, these sensing lines should be as short as possible and of equal length to each side of the pressure transducer.

To maintain high calibration accuracy, it is desirable to employ the same flow medium in the calibration as that to be used in the actual metering system. However, it was found by comparative tests with flowmetering devices designed for use with certain gases (helium, nitrogen, oxygen) that calibrations could be run more conveniently using dry air at constant temperature. The basis for using air as the flow medium and converting the test data to another gas conforms to accepted practice where the calibration does follow the ASME[1]—VDI[2] formulae.

If wide temperature differentials are expected during the calibration runs, it may be necessary to enclose the transducers in a temperature controlled housing at the temperature which will provide the most accurate results.

Cryogenic liquids, gases and mixed phase conditions require expert test personnel. For example, valves should be carefully opened or closed to prevent surging which could over-range transducers and invalidate the calibration; shocks to transducers which can damage the mechanical or electrical response should be carefully avoided. It is important to remember that steady flowing conditions should be maintained long enough for all instrumentation to stabilize at a specific rate. Of course, the system should be entirely leak free during the calibration run.

A minimum of three calibration cycles (up and down range three times) is considered good calibration practice for repeatability. In addition, a sufficient chart run at each calibration increment should be provided to show steady-state conditions. These data will also indicate good, repeatable transducer performance.

Both volumetric and gravimetric methods have been used for flowmeter calibration in the Atlas Missile static test programs. The volumetric method is used where the calibration is desired in gallons or cubic feet and no density factor is involved. Volumetric calibration is accomplished by comparing the number of gallons read by a meter with the quantity of fuel required to fill a prover tank, known to an accuracy of 0.05% (compared against a National Bureau of Standards Certification). The tank used in this calibration was a mobile unit designed and built by Convair, which could be transported from one site to another for in-place calibration (Fig. 2).

The *gravimetric* method consists of a precise *weighing* of a known volume of flowing media. In the Atlas program, this method was used at several Atlas test sites. The weighing was accomplished by an NBS-calibrated loadcell system which determined the weight (corrected by gravity and buoyancy effects) of a tank filled with a known volume of propellant.

Problems and Special Designs

Standard off-the-shelf flowmeters have not satisfied some of the critical applications where ex-

1. American Society of Mechanical Engineers
2. Verein Deutscher Ingenieure (German Industrial Standard)

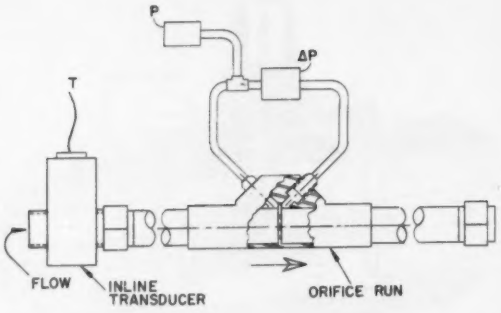


FIG. 3. MASS FLOW is measured by orifice and temperature transducers.

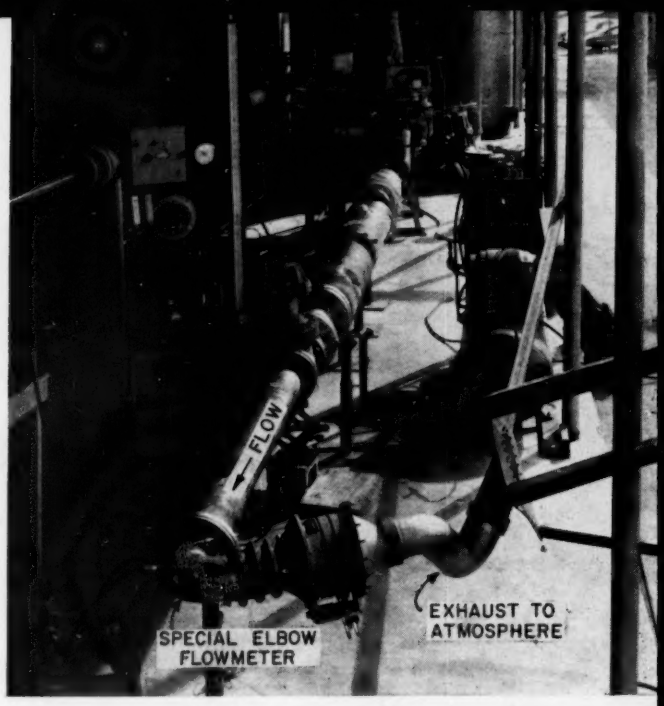


FIG. 4. ELBOW flowmeter.

tremes of flow rate, temperature and pressure and severe space and weight limitations were encountered. Such applications include:

1. High-pressure high-temperature helium gas flow at sonic velocity to rocket engine controls and tank pressurization lines.
2. Gaseous oxygen boil-off from liquid oxygen propellant tanks.
3. Measurement of flow of cryogenic liquids in a mixed phase condition (liquid and gas mixed flow).

In such applications it was found necessary to develop special flowmeter designs to satisfy the environmental and configuration conditions.

ORIFICE METERS

Measurement of the flow of gaseous helium to maintain tank pressures during flight was required to optimize airborne helium weight requirements. A *mass flow* measurement was required. It was necessary to install the primary sensing elements in small stainless-steel tubing runs without flanges because of space and weight limitations. Special consideration was given to straight tubing runs upstream and downstream of flow orifice to minimize turbulence.

An integral *sharp-edge orifice* with corner taps was developed for this special application. The weight of this unit is approximately one-tenth the weight of a standard orifice plate installed between gasketed flanges. Since no gasketing is required, the possibility of leakage in high-pressure high-temperature systems is minimized. An in-line temperature transducer together with a static pressure and a differential-pressure measurement (Fig. 3) provided a mass flow measurement. This was accomplished by developing a set of curves showing relationships of differential pressure, static pressure and temperature to mass flow rate as established by flow calibrations.

ELBOW FLOWMETERS

One of the metering requirements in the missile program was to measure the mass flow of gaseous oxygen boiled off from a liquid oxygen surface. It was necessary to design a special flowmetering device which could be incorporated with the boil-off ducting configuration because of space and weight limitations.

The measurement was accomplished by equipping an existing 110° radius elbow with pressure taps placed at selected locations determined by experiment. This was an approach based on the principle of centrifugal force exerted by a fluid flowing around a bend. Contrary to prior experience with such devices, it was found by actual flow tests that this new metering device possessed a high accuracy (comparable to an orifice) without the pressure drop limitations of the orifice. Fig. 4 shows the elbow flowmeter, with differential-pressure taps, static-pressure tap and temperature tap (from which mass flow rate is derived).

Future Developments

There is a great need at the present time for portable calibration facilities for cryogenic liquids and gases. With the tremendous increase in the use of oxygen, nitrogen, helium and hydrogen in military and commercial applications, the need for measurement of these materials has grown.

The accounting of transferred cryogenic materials from storage to use involves flow measurement in which a mixed phase condition is encountered. This is a very difficult flow measurement problem due to gas entrainment in the liquid and corresponding wide variations in density. An accurate metering function in such difficult transfer applications could be accomplished by portable calibration facilities involving accurate pressure, density, temperature and flow measurements with comparisons to suitable NBS-certified standards.

The Versatile Purge Meter

J. E. POWELL Manager, Varea-Meter Dept.
Wallace & Tiernan Inc.

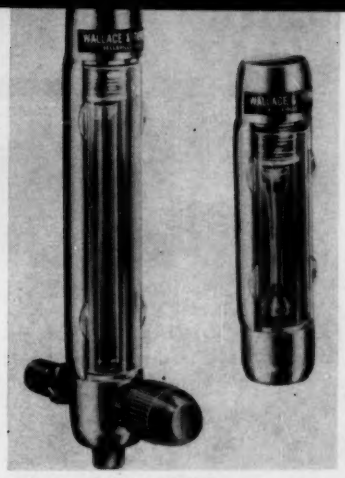


FIG. 1. GLASS-TUBE purge meters.

THE PURGE METER (Fig. 1) is a small variable-area rotameter-type flowmeter. It obtains its name from the fact that an early use of small rotameters was in monitoring the small flow in the purge lines of flowmeters. But the "purge meter," because of its simplicity and economy, is used today in tens of thousands of applications involving not only purging but also level measurement, sampling, venting, measurement of specific gravity, detection of leaks, etc.

Purge meters can accomodate flows of from less than 0.01 to more than 40 gph water, or from less than 0.10 to more than 110 scfh air. It is recognized that the larger sizes are more "flowmeter" than "purge meter."

Fig. 2 shows its use in *purging* flowmeter instrument lines. This application gives the purge meter its name. The small rotameter is used with a differential regulator (usually the spring-diaphragm type) which maintains a constant differential between the inlet and outlet. This establishes a constant flow through the purge meter, irrespective of the absolute pressure in the meter lines. The small flow purges the line and prevents the liquid in the line from reaching the meter body. Water is commonly used as purge media.

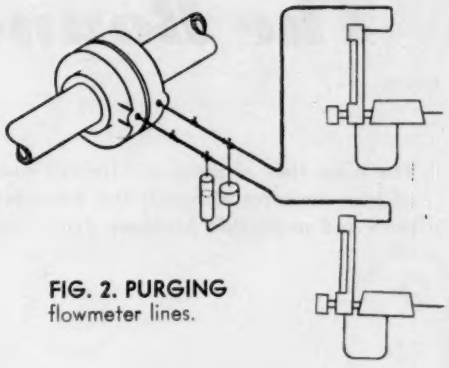


FIG. 2. PURGING flowmeter lines.

Fig. 3 shows use of a purge meter for measuring *level*. As the differential regulator always maintains a constant flow *rate*, the static pressure in the line downstream of the needle valve is always equivalent to the liquid head in the tank.

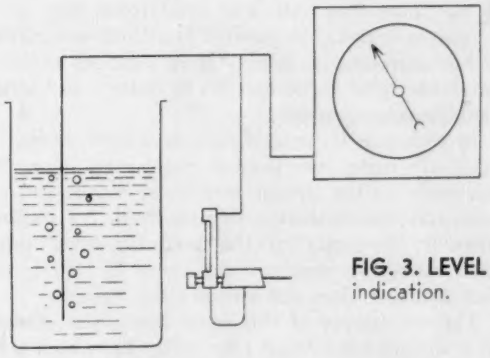


FIG. 3. LEVEL indication.

Specific gravity can be measured or controlled by using two dip tubes at different levels, as shown in Fig. 4, by using two purge meters. In this application, the pressure differential between the two lines to the measuring instrument is given by:

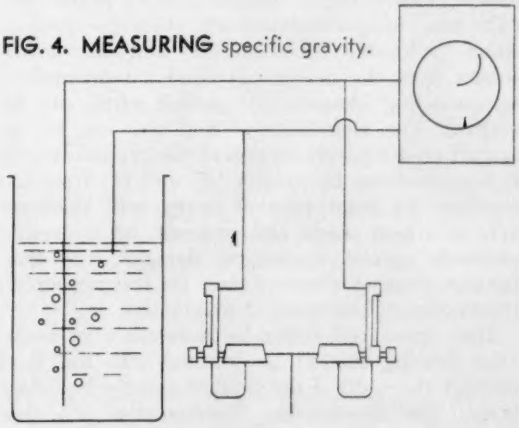
$$\Delta P = H(SG_1 - SG_2)$$

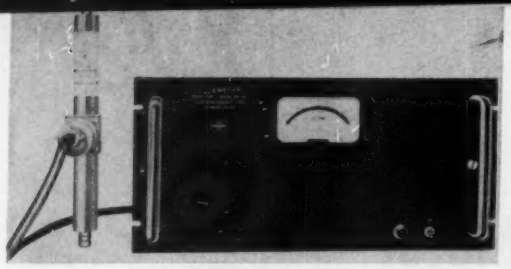
where H is the distance between the open ends of the dip tubes, SG_1 is the specific gravity of the fluid in the tank, and SG_2 is the specific gravity of the purge medium (air). Note that the ΔP is independent of the level of the tank and, if H and SG_2 are constant, depends only on specific gravity of the fluid in the tank:

$$P = H(SG_1) - (\text{constant})$$

Note that the scale is suppressed by the constant $H(SG_2)$, which usually is considered negligible.

FIG. 4. MEASURING specific gravity.





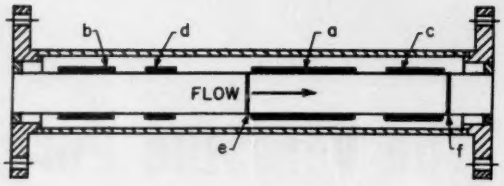


FIG. 1. BOUNDARY-LAYER mass flowmeter. Boundary layer is heated by heater (a). Temperature increase is sensed by transducer (c), compared to initial temperature sensed at (b). d provides compensation. (Photo courtesy Flow Measurements Corporation)

The Boundary-Layer Mass

The mass flow of gases and liquids can be measured accurately by determining the rate of heat transfer through the boundary layer of the fluid. The flowmeter has a smooth bore and negligible pressure drop, and measuring elements do not contact the fluid.

IN many operations it is desirable to measure the mass flow rate and total mass flow of a gas or liquid. Frequently, the fluid is a slurry or has corrosive qualities. Often rigorous sanitary standards have to be met, as in dairies and other food processing plants.

In recent years mass flowmeters have been developed[1] using mechanical measuring elements inserted into the stream, which are exposed to attack and contamination by the fluid. An electrothermal flowmeter of the boundary-layer type[2] uses measuring elements outside of the fluid conduit and thus does not obstruct the stream.

The transducer of this mass flowmeter consists of a smooth-bore metal tube (Fig. 1), which seals and protects the measuring elements from the stream. The elements include a small heater coil (a), two temperature-sensing elements—one of which is located upstream (b) and one downstream from the heater (c)—and a temperature-compensating element (d), which often can be omitted. The elements (a) and (c) can be arranged on a separate section of the conduit, which is heat-insulated by spacers (e) and (f) from the pipeline. An outer tube of heavy wall thickness acts as a heat shield and protects the measuring elements against mechanical damage. The temperature-sensing elements can be thermocouples, thermistors or resistance thermometers.

Heat, produced either by inductance or resistance heating in (a), is injected into the fluid through the walls of the conduit and the boundary layer. The downstream thermometer (c) then measures the resultant temperature of the outside surface of the boundary layer. The upstream thermometer (b) measures the initial temperature of the stream. Small temperature differentials across the boundary are sufficient for satisfactory operation.

It can be shown that the relation between heat flow Q, temperature difference Δt and mass flow rate F can be approximated closely by the following expressions for turbulent flow (Q_t) and laminar flow (Q_L):

$$Q_{(t)} = (A)(\Delta t)(C^{0.4})(K^{0.6})(F^{0.8}/\mu^{0.4}) \quad (1)$$

$$Q_{(L)} = (B)(\Delta t)(C^{1/3})(K^{2/3})(F^{1/3}) \quad (2)$$

where A and B are design parameters, C the specific heat, K the thermal conductivity and μ the viscosity of the fluid. Equations (1) and (2) are valid as long as the temperature gradient across the walls of the conduit is negligibly small compared with the temperature difference across the boundary layer. This can be assumed, ordinarily.

The relation between heat transfer and mass flow rate can be employed by either the *variable-temperature* or the *variable-power* method for measuring the flow rate, F. In the variable-temperature method, the heater power is held constant and the temperature differential between the upstream (b) and downstream (c) sensors is measured. In the variable-power method, Δt is held constant as the flow rate varies and the heater power measured. Heater power will be proportioned to Q_t.

JOHN H. LAUB
Jet Propulsion Laboratory

Flowmeter

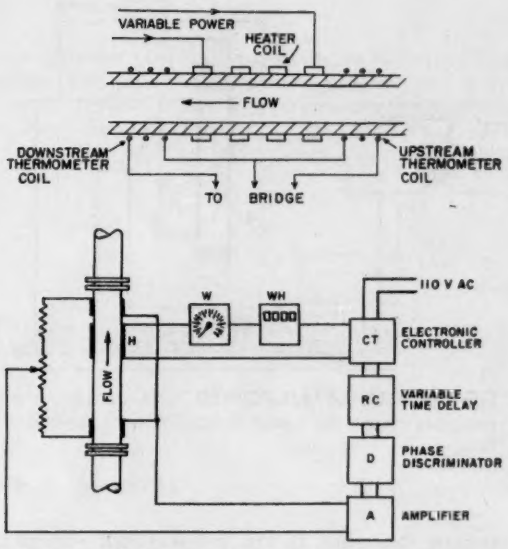


FIG. 2. VARIABLE-POWER (wattage) method.

Variable-Power Constant-Temperature Method

If the variable-power mode of operation is used, Δt is held constant by a self-balancing bridge and servo loop (Fig. 2). The flow rate then is read on a wattmeter (W), and the total flow on a watt-hourmeter (WH) in the heater circuit—after linearization of the output. The power signal also can be converted into a voltage signal by a thermal converter. The bridge is in balance as long as the flow rate remains constant. If a change occurs, the bridge becomes unbalanced and the error signal is detected and amplified in amplifier (A). The phase of the signal depends on whether the flow rate (F) increased or decreased; it is discriminated in (D). As the time lag of the transducer varies with the rate of flow, a time-delay network (RC) is inserted, whose time constant automatically varies with the flow rate to match the transducer lag. Bridge balance is restored by a power control unit (CT), which may use transistors, thyratrons, magnetic amplifiers, motor-driven power regulators, etc.

Fig. 3 shows the "unlinearized" calibration curve of a 1" ID flowmeter with water, operated in the variable-power mode. The measured values correlate well with the expressions (1) and (2) if the downstream thermometer is located close to the heater.

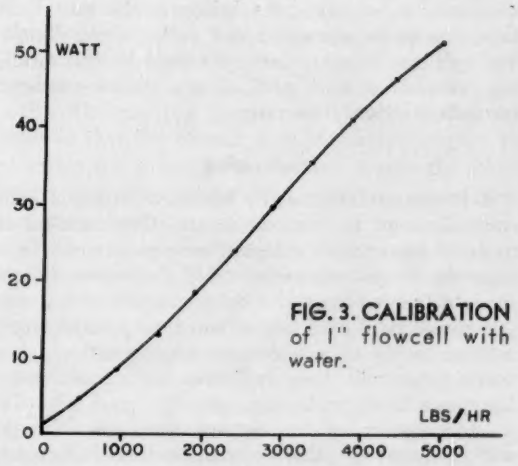


FIG. 3. CALIBRATION of 1" flowcell with water.

Variable-Temperature Constant-Power Method

If the flowmeter is operated by the alternate method of maintaining power constant, the output of the bridge is a millivolt signal proportional to Δt. The signal decreases with increasing flow rate (F) in accordance with expressions (1) and (2). Fig. 4 shows measurements of a mixture of kerosene and tributyl-phosphate in laminar flow. Note that the signal decreases as flow increases.

It is easy to obtain a signal which *rises* with in-

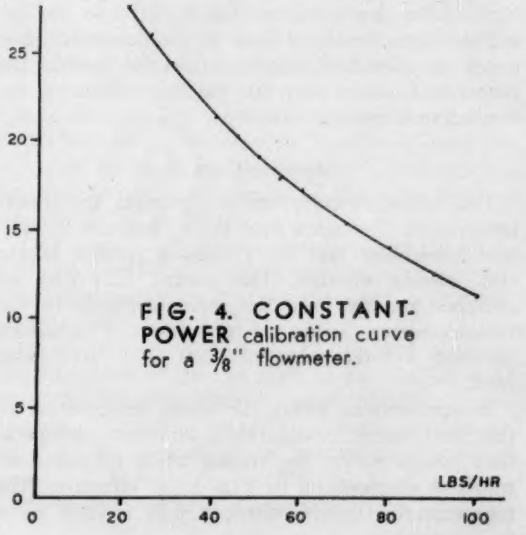


FIG. 4. CONSTANT-POWER calibration curve for a 3/8" flowmeter.

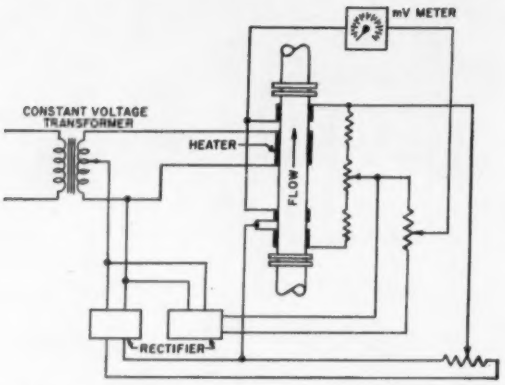


FIG. 5. CONSTANT-POWER arrangement that provides increasing meter indication with increasing flow.

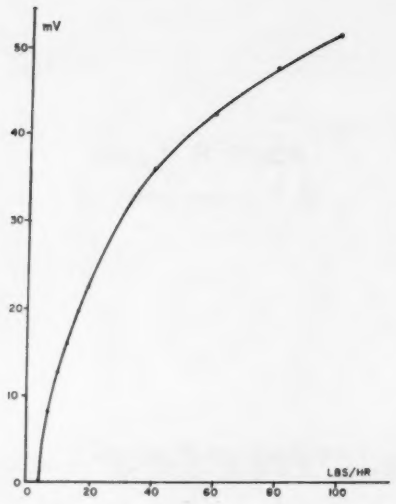


FIG. 6. CALIBRATION for laminar flow in 3/8" flowmeter.

creasing flow rate. In Fig. 5 the output voltage of the bridge is opposed by a constant voltage, and the difference between the two voltages is indicated on a millivolt meter. The same result can be obtained by balancing the bridge at the minimum flow rate to be measured and omitting the "bucking" voltage. Measurements obtained by this method are plotted in Fig. 6, which shows excellent resolution at low flow rates.

Linearizing

A linear readout can be obtained within a substantial range by various means. One method is to use a meter with a logarithmic movement, or a logarithmic potentiometer. Fig. 7 shows that a straight line is obtained if the logarithm of the output signal is plotted versus the flow rate. A logarithmic meter or a self-balancing logarithmic potentiometer will thus indicate and record mass flow on a linear scale.

Linearization of the output signal also can be accomplished by other conventional methods, such as function generators or cam-linked potentiometers. After linearization, the signal can be integrated to obtain total flow. As the flowmeter produces an electrical signal, it can be readily incorporated into systems for logging, digitizing, recording or automatic control.

Applications

The boundary-layer method permits the measurement of flow rates over large ranges with only one transducer and by switching in the heater and sensing circuits. The circuit also can be switched readily from the constant-power to the variable-power mode of operation. Flowmeters covering a total range of 1200 to 1 have been built.

In applications where the initial temperature of the fluid varies considerably, automatic temperature compensation by means of a temperature-sensitive element (d in Fig. 1) is effective. The temperature-sensitive element may consist of a

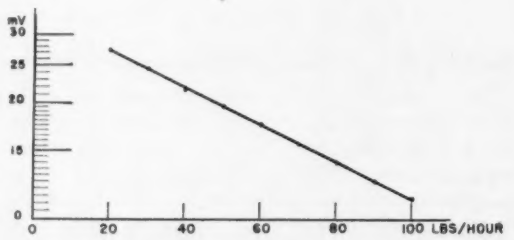


FIG. 7. LOG PLOT of output signal using constant-power method for laminar flow.

small coil of nickel wire. In the variable-power method this is inserted into a fixed resistance arm of the bridge to keep it in balance during changes in initial temperature. If the flowmeter is operated in the constant-power mode, the voltage across the temperature-sensitive element is added to the output signal of the bridge.

The boundary layer is thin, and the power required to raise its temperature a few degrees is small; approximately 1 watt is used per 1000 pounds/hour flow. The *response time* is fast; it varies between fractions of a second and several seconds, depending on the rate of flow and the thickness of the wall.

The effect of changes in the composition of the stream—with attendant variations of the significant parameters of the fluid (viscosity, specific heat and thermal conductivity)—have been calculated for various fluids. The error generally is small, except where the composition changes substantially and the effect of the fluid parameters is cumulative. In such cases automatic compensation can be accomplished by monitoring the composition.

References

1. Siev, Robert, "Mass Flow Measurement," *Instruments and Control Systems*, Vol. 33 No. 6, June, 1960, p 966.
2. Laub, J. H., "An Electric Flowmeter", *Electrical Engineering*, December, 1947, p. 1216.

The pitot tube in this flow detector is simply a hole in a cylinder (tubing) which spans the pipe. This piezometer hole looks upstream to sense impact pressure. The pipe contains wall (piezometer) holes for static pressure. The only important source of error results from the blocking effect of the small transverse cylinder on the wall piezometers. For normal turbulent flow, the pitot coefficient is given by a simple equation involving the ratio of the cylinder-to-pipe diameters.

Coefficient of a Pitot-Tube Flow Detector

J. M. ROBERTSON and F. E. SHUSTER

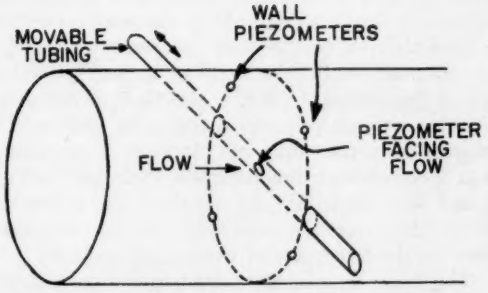


FIG. 1. TRANSVERSE cylinder has hole to detect impact pressure (impact piezometer). Wall holes (static piezometers) detect static pressure.

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A PITOT TUBE for detecting flow can be made simply by spanning a pipe with a small tube containing one piezometer hole for measuring the impact (stagnation) pressure. The tube is installed normal to the flow and usually extends through packing glands in both pipe walls. The packing glands also permit sliding the tube so that the impact hole traverses the pipe to measure the velocity distribution across the pipe. Such pitot tubes have been used by several researchers.[1,2]

Static pressure is measured best with several wall piezometers (holes) located about the pipe circumference in a plane tangent to the front of the cylinder—i.e., in the plane of the piezometer hole used to measure the stagnation pressure (Fig. 1). This location avoids errors that would result from the longitudinal pressure gradient along the pipe. The results presented here are for this recommended location; no study was made of the significance of position along the pipe in affecting the calibration (although it may be considerable).

In using such a transverse pitot tube, the impact piezometer must point "into the velocity" and not at some angle to the pipe axis. Fortunately this orientation is not critical, and can be achieved easily with the aid of a line inscribed along the cylindrical tube so that its angular orientation can be observed on the portion of the tube that extends outside the pipe.

This simple construction was used by Hiram F. Mills in the 1870's. Velocity of flow can be measured accurately as long as there are not large transverse pressure variations.

In an experimental research program at Penn State University[3] on the flow in nozzles, straight pipe, and diffusers, the transverse cylindrical pitot tube was adopted as the principal means of velocity measurement because of its simplicity and ease of insertion. The velocity distribution in 6" to 12"-diameter sections was measured with a ¼"-diam-

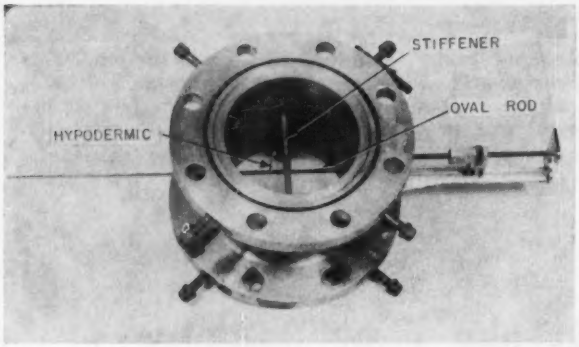

FIG. 2. HYPODERMIC pitot tube in 6" pipe section.

eter tube, with the static piezometers drilled in the wall of the conduit. These wall piezometers were located about the pipewall, in a plane normal to the conduit axis at the leading edge of the cylindrical tube, and at angles of 30 or more degrees from the axis of the tube (see Fig. 1).

During the course of the experiments it was noted that the integrated discharges obtained were significantly higher than those given by a calibrated weir. This cast doubt on the reliability of this pitot tube, and a special investigation was made on the possible source of error.

Error Analysis

Error in flow measurement can arise from either the impact- or static-pressure piezometers. In most pitot tubes the impact hole pressures are subject to error due only to the turbulence in the fluid stream.* In the transverse pitot tube it is possible that in a region of steep velocity gradient (such as near a wall), a transverse flow can develop along the front of the cylinder, thus introducing additional error in the impact pressure.

With properly-constructed wall piezometers the only possible error in the static pressure would result from the blocking effect of the transverse rod, which tends to cause the velocity past the wall piezometers to be higher and the pressure lower than would result if the tube were not present. Investigation of the errors of the transverse cylindrical pitot indicated which of these two possible sources of error is the major one, and resulted in quantitative information on the magnitude of the correction that must be made to obtain the true velocities, as follows:

Experiments and Analysis

A special hypodermic-type pitot (Fig. 2) was built into a 6" pipe section to measure the errors introduced by the transverse pitot tube. This hypodermic (18-gage 0.029"-OD tube) projects upstream of the oval transverse support rod. The open impact hole of the hypodermic and the wall piezometers are far enough away from (about 0.9" upstream of) the support rod to be out of its influence region and thus unaffected by the transverse tube. The support rod was slid so that the hypodermic pitot traversed the pipe.

Readings with the hypodermic were compared with those taken while traversing with the cylindrical tube at the same cross section and rates of flow. It was found that the indicated velocities in the center of the pipe were *higher with the cylindrical tube than with the hypodermic unit.* As the velocity gradient was zero in the central region, *this discrepancy could result only from errors in the indications of the wall piezometers.*

The errors in the wall piezometers due to the ¼" cylindrical transverse tube then were determined in flow sections of 6.06", 6.64" and 10.21" diameter. This was done by measuring the pressure drop between an upstream reference piezometer and the piezometers in the plane of the leading edge of the pitot. Then the same pressure drop was measured without the transverse tube in place. The difference (Δp) is due only to the transverse tube.

These errors in the wall piezometer indication are given in Table 1, in terms of $2\Delta p(\rho V^2_{av})$ where Δp is the pressure error, ρ the fluid density, and V_{av} the average velocity in the cross section. This expression, rather than Δp alone, is used because it is a convenient dimensionless form and includes ρ and V_{av}. As would be expected for a blocking effect, the errors decrease with increase in conduit size for the fixed size of the cylindrical tube.

The manner in which static pressure indicated by a wall piezometer is influenced by the proximity of a transverse rod has been studied by C. W. Hubbard[4]. Hubbard measured the change in pressure induced at a wall piezometer by an adjustable dummy rod reaching from the wall to the center of the pipe. His results indicate that the error depends greatly on the relative position of the piezometer and rod. The average velocity-correction factor given by Hubbard for wall piezometers used with a cylindrical transverse pitot is about 0.45 multiplied by the ratio of projected area of the tube (tube diameter d times pipe diameter D) to the cross-sectional area ($\pi D^2/4$). This gives the velocity error (ΔV) in terms of the average velocity (V_{av}):

$$\Delta V = V_{av}(0.45)(dD)/(\pi D^2/4) \qquad (1)$$

This small error in velocity produces the error in the *pressure* indicated by the wall piezometers. This pressure error can be found by applying Bernoulli's Theorem, written in the familiar form:

$$(p/w) + (V^2/2g) = \text{constant} \qquad (2)$$

where p is the pressure in the fluid and w is its specific weight. Any pressure error Δp can be found from equation (2) as follows:

$$\Delta p/w = (p_{av}/w) - (p/w) = (V^2/2g) - (V^2_{av}/2g) \qquad (3)$$

where p_{av} = true average pressure and p is the indicated pressure (average of the wall piezometers in this case). The velocity V also can be ex-

*The coefficient of a needle-type pitot tube is unity except for turbulence effects and lateral velocity gradients. Thus the coefficient of a pitot tube corrects primarily for the errors in the indications of the static (or ambient) piezometers, as this work illustrates.

Table 1—Wall Piezometer Error* due to ¼" Cylindrical Pilot

Section Diameter (Inches)	Error (Measured)	Error (Computed)
6.06	0.042	0.047
6.64	0.047	0.043
10.21	0.004	0.028

*Error $= \Delta p/(\rho V^2_{av}/2)$, where Δp is pressure error, ρ is fluid density and V_{av} is average velocity in cross-section of pipe.

pressed as $V_{av} + \Delta V$ so that the pressure error (equation 3) appears as:

$$\Delta p/w = (V_{av} + \Delta V)^2/2g - (V^2_{av}/2g)$$

$$= [V^2_{av} + 2(\Delta V)V_{av} + (\Delta V)^2]/2g - [V^2_{av}/2g] \quad (4)$$

If $(\Delta V)^2$ is insignificant compared to the term $2(\Delta V)\ V_{av}$, equation 4 becomes:

$$\Delta p/w = 2\Delta V\ (V_{av}/2g) \quad (5)$$

Substituting (1) into (5) gives:

$$\Delta p/w = 2\ [(0.45)(d)(D)V_{av}/(\pi D^2/4)](V_{av}/2g)$$
$$= 1.145\ (d/D)\ (V^2_{av}/2g)$$

Since $w/g = \rho$, the density:

$$2\Delta p/\rho V^2_{av} = 1.145\ d/D \quad (6)$$

$$\Delta p/\rho V^2_{av} = 0.572 d/D$$

This is a convenient expression for the pressure error Δp because it is a dimensionless term and involves ρ and the average velocity.

The piezometer errors computed from equation (6) are compared with those measured, in Table 1. The agreement is good, except for the 10" diameter section, where the values of $\Delta p/w$ were quite small and could not be measured accurately.

Correcting the wall piezometer readings according to equation (6), the velocities measured in the 6" pipe with the cylindrical pitot and the hypodermic-type pitot are shown in Fig. 3. The agreement is seen to be close, even near the wall where the velocity gradient is steep.

Agreement between the cylindrical and another hypodermic-type pitot in an 8.26"-diameter section where the boundary layer was much thicker also was good. Thus the cylindrical transverse pitot-tube readings appear to be independent of the transverse velocity gradient, and the only correction necessary is due to the interference effect of the tube on the wall piezometers.

Conclusion

The results of the study permit one to predict the coefficient of the transverse pitot as a function only of the ratio of pitot diameter to pipe section diameter. From equation (6) the pitot coefficient is:

$$C = V/V_i = 1 - (0.572)(d/D)(V_{av}/V_i) \quad (7)$$

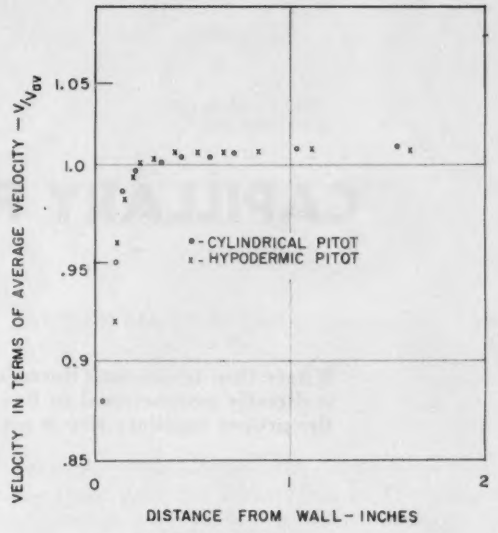

FIG. 3. COMPARISON of velocities obtained in 6" pipe with cylindrical and hypodermic pitot tubes.

where V_i is the velocity one would compute from the difference between the impact and static pressures for a unity pitot-coefficient. The coefficient is thus a function of the ratio of the apparent velocity to the average velocity in the cross-section. Usually the average velocity is not known and the coefficient must be determined by successive approximations, the first approximation being that for V_{av}/V_i of unity, for which:

$$C = 1 - 0.57(d/D) \quad (8)$$

Using this value of C, the velocity distribution and an approximate value of V_{av} is obtained for insertion into equation (7)

If the correction is small, the second approximation is adequate. If the velocity distribution has not been disturbed by the proximity of expansion valves, bends, etc., and the flow is turbulent, the first approximation may suffice. For example, a ¼" pitot in a 6" pipe has an average C of 0.976. If account is taken of the velocity distribution (with 1/7th-power-law turbulent-velocity profile) the pitot coefficient is 0.5% less near the wall (0.05 D from the wall) and 0.5% greater at the center of the pipe. Thus the variation in C with transverse location is small, in the usual case. For most turbulent-flow applications equation (8) can be used to obtain the coefficient of a transverse cylindrical pitot tube. If an abnormal velocity distribution exists, equation (7) must be used for accurate work.

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CAPILLARY FLOWMETERING

Where flow is viscous (Reynolds number less than 2000), head loss is directly proportional to flow rate. Here is how to make sure that the proper capillary size is used for viscous-flow rate measurement.

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Whittier, California

Nomenclature, Terminology, Equations

h_L = head loss in feet of fluid, feet
L = Length of tube, feet
V = Velocity of fluid, ft/sec
g = Acceleration of gravity, ft/sec²
D = Internal diameter of tube, ft
μ = Absolute viscosity of fluid, lb-sec/ft² (poises/478)
ρ = Mass density, slugs/ft³ or lb-sec²/ft⁴
f = Friction factor, dimensionless
RN = Reynold's number, dimensionless
w = specific weight, lb/ft³ = ρg
Q = Volumetric flow rate, ft³/sec, (V x A)
A = Area, ft²
c = sonic velocity, ft/sec
M = Mach number, dimensionless
k = ratio of specific heats, c_p/c_v, dimensionless
R = Gas constant, 1544/molecular weight
T = Temperature, °R (°F + 459)
P = Pressure, lb/ft²

(1) Darcy equation: $h_L = fLV^2/2gD$. General equation relating pressure drop to fluid velocity. Units are ft-lb-sec.

(2) Reynolds number $RN = \rho VD/\mu = 4\rho Q/\pi D\mu$

(4) Poiseuille-Hagen relation: $h_L = 32\ \mu LV/g\rho D^2$. Shows that head loss is proportional to velocity; units are ft-lb-sec

(6) Poiseuille-Hagen relation: $Q = D^2A\ (\Delta p)/32\mu L$. Relates Q and head loss. Units are ft-lb-sec

$c = \sqrt{k\ g\ R\ T}$, equation for velocity of sound in a gas.

Viscous (laminar, streamline) flow. Fluid moves by sliding of laminations of adjacent layers. Particles move in definite paths or streamlines. Characteristic where viscosity plays a significant part. Flow is usually viscous at Reynolds number less than 2000.

Turbulent flow is irregular, with no observable pattern; usually occurs at Reynolds number above 4000.

Disturbed flow is when large eddies, swirls and irregular movements of large bodies of fluid can be traced to sources of disturbance. This does not constitute turbulence.

SMALL fluid (gas or liquid) flow rates can be measured by a direct-reading flowmeter based on the Poiseuille-Hagen principle of viscous drag through small-diameter tubes at low Reynolds Numbers. Such a meter can be constructed from a short length of commercially-available tubing sized so that the flow will be well within the viscous region. The head loss then will be directly proportional to the rate of flow and thus the rate of flow can be read directly on a manometer which measures the loss of head through the tube.

Theory

Reynolds developed the general relationship covering both viscous and turbulent flow. The more general equation covering pressure drop due to fluid friction is the Darcy equation:

$$h_L = fLV^2/2gD \qquad (1)$$

where (f) is the friction factor, a function of the Reynolds Number (RN):

$$RN = \rho VD/\mu \qquad (2)$$

As area $A = \pi D^2/4$ and $Q = VA$,

$$RN = 4\rho Q/\pi D\mu \qquad (2)$$

Reynolds found that viscous flow took place at $RN < 2000$, and that in that range the friction factor

$$f = 64/RN \qquad (3)$$

Substituting (2) and (3) in the Darcy head-loss equation (1) gives:

$$h_L = 32\ \mu LV/g\rho D^2 \qquad (4)$$

which is the Poiseuille-Hagen relationship for viscous flow.

The important point is to make certain that flow is within the viscous range in order that the velocity is directly proportional to pressure drop.

Since gas flow is usually expressed in ft³, we can express equation (4) thus:

$$V = g\rho h_L\ D^2/32\ \mu L$$

$$Q = VA = g\rho h_L\ D^2A/32\ \mu L \qquad (5)$$

But $g\rho = w$ lb/ft³, and $g\rho h = \frac{w\ lb}{ft^3} \times h$ ft

$$= wh\ lb/ft^2 = \Delta p$$

where Δp is the pressure drop in lb/ft². Hence (4) becomes:

$$Q = D^2A(\Delta p)/32\,\mu L \qquad (6)$$

where Q is ft³/sec and A is the cross-sectional area of the tube in ft². Equation 4 or 6 can be used to design a viscous-flow metering system.

Sample Problem

Assume it is desired to measure the rate of flow of air (about one cubic foot per hour) at 70°F at sea level. To ensure being well within the viscous range, take RN = 800 for a first approximation:

$$w_{air} = P/RT$$

$$= \frac{(14.7)(144)}{(53.3)(530)} = 0.0750 \text{ lb/ft}^3$$

$$\rho = 0.075/g = 2.33 \times 10^{-3} \text{ lb-sec/ft}^4$$

$$Q = 1 \text{ ft}^3/\text{hr} = 1/3600 \text{ ft}^3/\text{sec}$$

$$= 2.775 \times 10^{-4} \text{ ft}^3/\text{sec}$$

$$\mu = 3.76 \times 10^{-7} \text{ lb-sec/ft}^2$$

Using equation (2) to solve for D; with RN = 800:

$$D = \frac{4 \times 2.33 \times 10^{-3} \times 2.775 \times 10^{-4}}{800 \times 3.76 \times 10^{-7}}$$

$$= 0.00274', \text{ or } 0.0329''$$

This is the tubing required to give a RN of 800 at a flow of 1 cubic foot/hr.

The closest commercially available stainless-steel tubing has an I.D. of 0.033" (D = 0.00275'). Let us now find the head loss using this available tubing. Using equation 2 (or equation 5):

$$h_L = \left(\frac{64}{RN}\right)\left(\frac{LV^2}{2gD}\right) = \frac{64}{800}\,\frac{LV^2}{2g \times .00275}$$

We find V from equation V = Q/A, A = $\pi D^2/4$,

$$V = 4Q/\pi D^2$$

$$V = 4\,(2.775)\,(10^{-4})/\pi\,(0.00275)^2$$

$$= 46.6 \text{ ft/sec} \qquad (7)$$

Substituting (7) in (2), using RN = 800, gives:

$$h_L = 980L \qquad (8)$$

giving a pressure drop of 980' air per foot of tube. This is equivalent to 1.18' or 14" of water per foot of tube length, for 1 cu ft/hr air flow (980 x 0.075/62.4 = 1.18).

This means that if a tube of 0.33" inside diameter is selected for the flowmeter, a water manometer with taps set 1' apart on the tube will show a differential pressure of over 14" for a flow rate of 1 cubic foot per hour of air at 70°F at sea level.

Ordinarily it is desirable to place the pressure taps on the circumference of the tube (Fig. 1). Construction is simplified if the upstream tap is placed on the upstream tank, and the other exposed to the atmosphere or to the discharge pressure if the gas is discharged in a container. A slight error will result, but should be inconsequential. The entrance loss will not exceed 0.5 velocity* heads

*Velocity head = $V^2/2g$

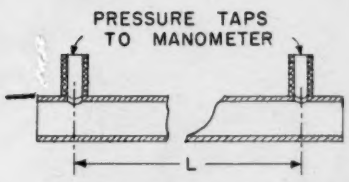


FIG. 1. MANOMETER taps on capillary tube.

and the exit loss will equal one velocity head. Combining these gives 1.5 velocity heads. These losses would equal:

$$1.5 \times V^2/2g = 1.5 \times 46.6^2/64.4 = 50.6' \qquad (9)$$

This amounts to an error of 50.6/980 = 5.16% at the maximum flow rate of 1 ft³/hr, which might or might not prove objectionable.

Another possible source of error lies in considering the flow of the air as incompressible. The magnitude of this error is approximately $V^2/4c^2$ or $M^2/4$, where c is the sonic velocity and M is the Mach Number.

$$c = \sqrt{kgRT} = \sqrt{1.4g(53.3)(530)}$$

$$= 1130 \text{ ft/sec}$$

$V^2/4c^2 = \frac{1}{4}(46.6/1130)^2 = 4.25 \times 10^{-4}$ (or 0.04% error due to ignoring the compressibility of the air).

Example 2

It might be desirable to select the diameter of the tube to show a particular pressure drop at a specific flow rate. This also can be done. Suppose it is desired to use a draft gage with a maximum pressure differential of 2" water to measure the flow rate Q_{max} = 1 ft³/hr, with pressure and temperature conditions the same as before.

2" water = (2/12) (62.4/.075) = 139' air

From (4), $h_L = \frac{32\mu L}{g\rho D^2}\left(\frac{4Q}{\pi D^2}\right)$

Substituting $\mu = 3.76 \times 10^{-7}$, $Q = 2.775 \times 10^{-4}$, $W = g\rho = 2.33 \times 10^{-3}$, h = 139.

$$D^4/L = 408 \times 10^{-12} \text{ ft}$$

For L = 1', D = 0.0045' = 0.054".

Tubing of 0.054" ID is available commercially.

In this case it is necessary to check the Reynold's Number to be sure that the flow is completely viscous:

$RN = 4\rho Q/\pi D\mu = 487$

This is well within the viscous range.

As pressure drop is proportional to velocity, the manometer or draft gage can be graduated directly in units of flow instead of units of pressure and a direct-reading flowmeter will result.

In this latter example the errors can be calcu-

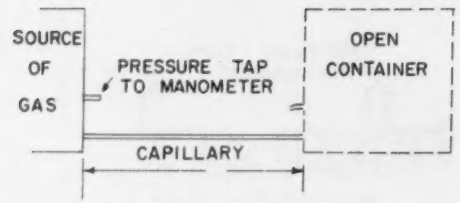


FIG. 2. **CAPILLARY** between pressurized source and open tank.

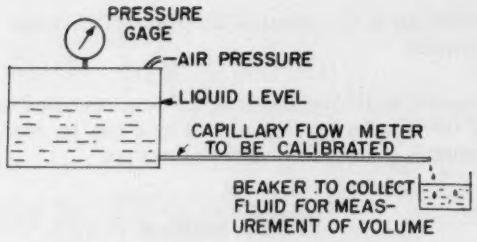


FIG. 3. **CALIBRATION** of liquid flow by weight or volume.

lated as before, but they will be appreciably less because the velocity is lower.

Minimum Flow

It is of interest to note the minimum rate of gas flow which can be detected accurately with such a flowmeter. Let us consider hydrogen, the lightest of all gases, and the one producing very low head. For H_2 at 70° (529°R), the μ is 88.9 x 10^{-6} poises and $\rho = w/g = 0.00518/32.2$.

The minimum diameter of tubing readily obtainable commercially is 0.004″ ID in stainless steel. Assuming a 3′ length of 0.004″ tubing and using equation (4):

$$h_L = 31{,}000V \qquad (11)$$

or the head loss will equal 31,000′ of hydrogen per ft/sec velocity through the tubing.

RN for hydrogen is: $RN = \rho DV/\mu = 0.288V$

Or, RN = 0.288 times the velocity (in ft/sec) for hydrogen flowing through a 0.004″ ID tube at 70°F.

If RN is to be kept below 2000, as RN = 0.288V, then any velocity below 2000/0.288, or 6950 ft/sec, will ensure viscous flow through the tube.

If a 2″ water draft gage is selected to measure the pressure drop, the max h_L required will equal (2/12)(62.4/0.00518) = 2010′ of hydrogen, or about 1/6 of 12,050′ (the theoretical height of uncompressed hydrogen which gives a pressure equal to the pressure of 1′ of water).

Since $h_L = 31{,}000V$, V = 2010/31,000 for a head loss of 2010′ of hydrogen, or 0.0648 ft/sec, giving a quantity flow Q:

$$Q = VA = (.0648)(\pi/4)(.004/12)^2$$
$$= 5.66 \times 10^{-9}\ ft^3/sec = 0.0350\ in^3/hr$$

This illustrates that the lower limit of measurable flow of such a flowmeter is close to zero. The full-scale-reading flow would be 0.0350 in^3/hr; or 0.000175 in^3/hr minimum reading (from 0.035/200, assuming a 1-part-in-200 readability).

Calibration

One important point: the diameter of the tubing obtained for use in constructing a flowmeter never will be exactly the dimension assumed for the calculations. In addition, the inside diameter will probably vary slightly along the length of the tube. This means that each flowmeter must be calibrated individually before use. This can be done by using a liquid as the calibrating medium. The flowmeter calculated previously for use with air (which was to show a pressure differential of 2″ of water for a flow rate of 1 cubic foot per hour) will be used as an example. The tubing diameter selected was 0.054″. The actual ID will be either a little larger or a little smaller and, as pressure drop for a constant quantity flow rate is inversely proportional to the fourth power of the diameter, the amount of this variation must be known. Selecting water as the calibrating medium, we first determine the flow rate as a function of diameter to calibrate the flowmeter.

μ for water at 68°F = 2.10 x 10^{-5} lb-sec/ft^2

$$h_L = 32\ \mu LV/g\rho D^2$$
$$= 40.8\ \mu LQ/wD^4$$

Taking L = 1′; Q = 1 ft^3/sec, D = .054/12′, w = 62.4 lb/ft^3, gives h_L = 33,400′ of water drop per ft^3/sec flow.

For a pressure drop of 100 psi this would give a flow equal to (231) (449)/33,400 = 3.11 gal/min. (where 231′ of water pressure is equivalent to 100 psi and 1 ft^3/sec equals 449 gpm). One form of test apparatus is shown in Fig. 3.

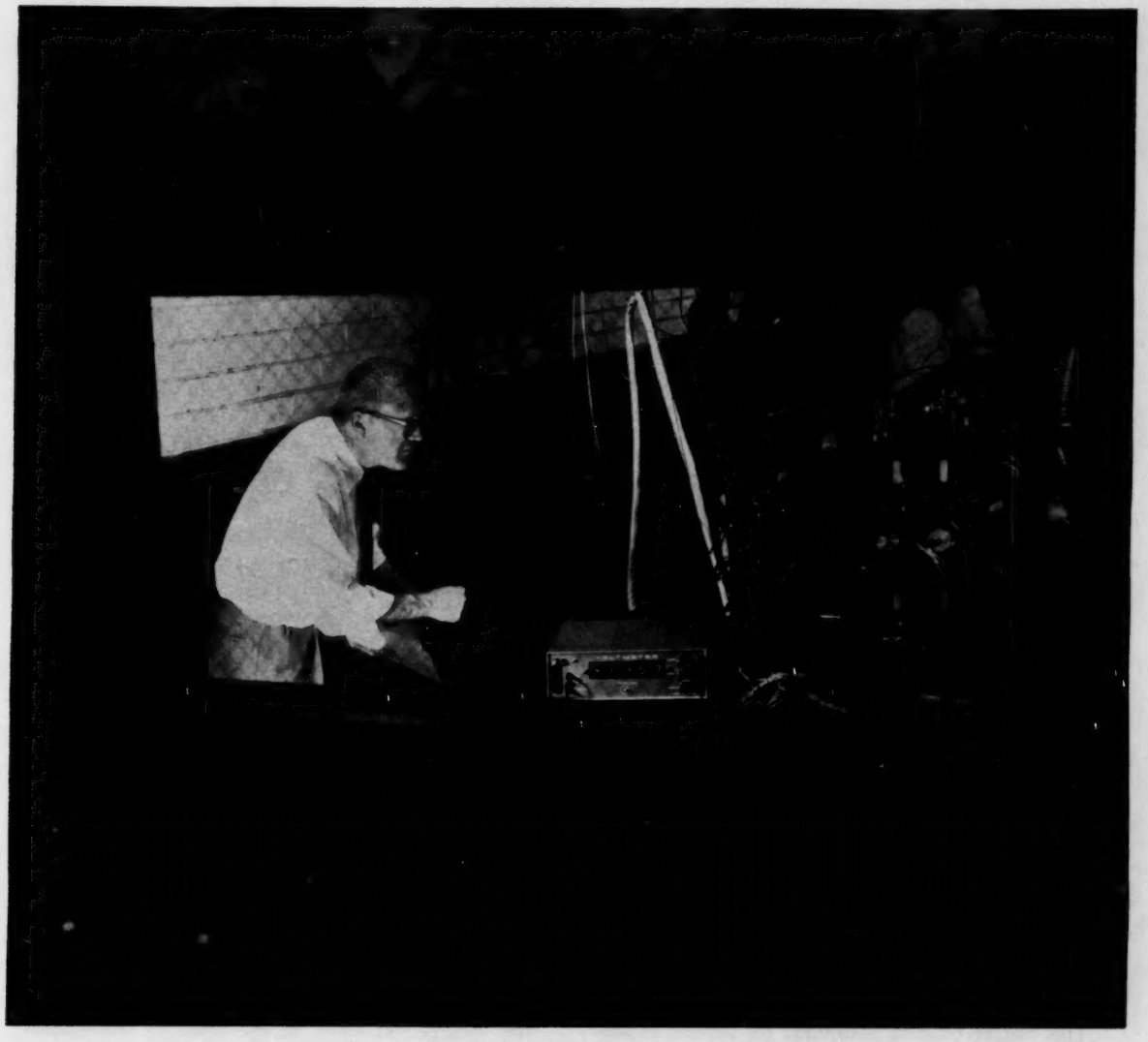
Rearranging the flow formula gives:

$$D^4 = 40.8\ \mu LQ/wh_L$$

Calibration of the meter, or determination of the effective tube diameter, then could be achieved by supplying water at a constant pressure of 100 psi and measuring the flow through the tubing in gallons per min.

$$D\ \text{effective} = 0.054\sqrt{Q/3.11}\ \text{inches}$$

The volume of fluid used during the calibration of the capillary flowmeter is small. The reservoir tank can be pressurized at the start of the test and the air supply line then closed. If the volume of the air space above the fluid is maintained at over 200 times the volume collected in the beaker during the calibration test, the error due to the reduction in pressure during the constant-temperature expansion would be only ¼%.



NO STEPPING SWITCHES IN THIS ULTRA-RELIABLE DVM:

Cubic announces a new digital voltmeter design that eliminates stepping switches and, with them, the need for periodic maintenance. The new Cubic V-70 uses the same ultra-reliable reed relays developed for submarine cables. These reed relays are sealed in glass and have practically unlimited life. They are noiseless and completely unaffected by operating position.

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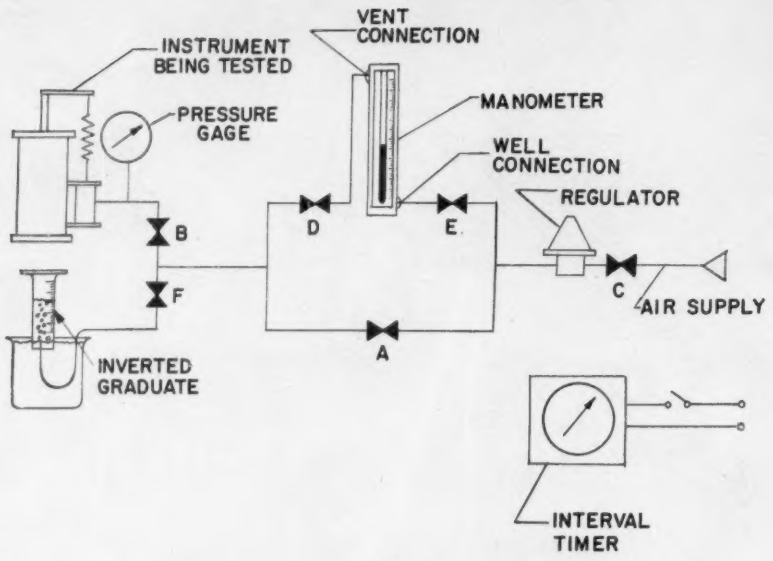


FIG. 1. MEASURING instrument quiescent air leak. Flow to instrument develops pressure drop across valve A that is indicated by manometer. Manometer permits operator to establish identical flow rate that is trapped and measured over a finite time interval.

Measuring Quiescent Air Leak

JOHN E. FLIPPIN, Steubenville, Ohio

WHEN a pneumatic instrument has reached the model stage, an engineer is usually assigned the task of writing up its specifications, which includes quiescent air leak—the amount of air the instrument uses when dormant. This can be hard to determine for several reasons. First, the usual method of measuring the air leak, or any flow, is by a flowmeter. However, most flowmeters will not respond accurately to the small flows resulting from the quiescent leak. About the only method left is to terminate the leak in water and capture it in a graduate. This is fine if you can isolate the leak, but too often you will find the source is general; it may come from more than one source or be terminated in an unreachable spot. You could submerge the entire instrument; but many instruments are either too large, permanently fixed to mountings, or contain precision parts that would be damaged by being submerged.

All of these problems can be circumvented by using a *"simulated flow method."* This SFM uses a pressure differential across a manometer as an indication of flow to the instrument under test. The pressure differential reading is recorded and used to establish an identical rate of flow, which is captured and measured as a function of time.

The test circuit is shown in Fig. 1. While hooking up, be sure that valve A is wide open and valves BCDEF are tightly closed. This will prevent an accidental pressure differential across the manometer. If you forget this, you might blow the manometer and end up having an instrument full of water or, even worse, mercury! Also make sure that you connect both ends of the manometer into the line. If you leave an end open to atmosphere you can end up with mercury all over the floor.

If you suspect that the quiescent leak is small, use a water manometer. If it looks as though you might have a flow over 3 cfm or so, use a mercury manometer; but you're getting into flowmeter range now. If in doubt, use the tallest column you have and work down to a smaller one, if you wish, but choose the indicating fluid that will give the best results.

Procedure

As valve A is already open, start out by opening valve B all the way; then *slowly* open valve C, making sure that the column doesn't begin to rise. If it does, something is wrong; go back and make sure that valves D and E are closed. If everything is ok, finish opening valve C and wait for the instrument to settle down. If the instrument is a positioner or a controller, it will finally come to rest and the only flow to it will be due to the quiescent leak. Check the pressure gauge to see that supply pressure is up to specifications. If it isn't, adjust the pressure regulator until it is.

Now open valves D and E—slowly and simultaneously, if possible. If the manometer fluid begins to rise quickly, you're in trouble; but usually it will just slowly bounce around and settle down after D and E are opened. Make sure now that no one is fumbling around with the instrument under test. Should it once leave the quiescent stage, even momentarily, the manometer will blow; unless you have an enormous valve at A, but don't depend on this. Most instruments will require a large surge of flow while in the transient state.

With the setup as you now have it, the manometer should be reading zero—that is, there should be no pressure differential across valve A. Begin—slowly again—to close valve A. If the slightest motion on valve A causes the manometer fluid to shoot up, open valve A immediately. This indicates valve A is not of sufficient capacity to get a good reading. In this case, replace valve A with a larger valve. You want to throttle valve A so that you get a measurable pressure drop across it. If you get a good reading (well up on the manometer) after valve A has been reduced to only a turn or so from closed, fine; you're almost ready to start testing. If this doesn't do the trick, you're manometer is probably too sensitive. In this case, switch to a heavier fluid—mercury, if you're using water.

When you get a sufficient height in the manometer, mark down the pressure indication. Now, slowly shut off valve B and leave it off for the remainder of the test. The manometer will be reading zero. Open valve F until you get the same reading on the manometer that you had previously. This indicates the flow through valve F is identical to the quiescent leak of the instrument.

Put the hose (connected to valve F) in the water container. If it bubbles violently, you will need a large graduate; if it bubbles gently, a small one. Submerge the graduate in the water container to fill it. Invert it and withdraw it above the surface of the water until the last graduation (largest calibrated volume) is in line with the surface.

Unless you are ambidextrous and three handed, the next step will require an assistant (or a timer with a foot switch). Have the assistant stand ready; When you insert the hose in the graduate, have him turn on the timer simultaneously. Allow the leak to pump out the graduate until the level inside reaches the last graduation (just in line with the surface of the water). Signal the assistant to shut off the timer, and then close valve C.

This will give you the data for determining the instrument leak in CFM. Say, for example, that it took 60 seconds to pump out 1000 ml of water. Then:

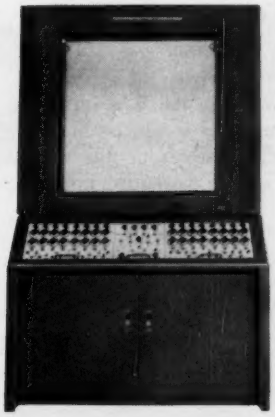
1000 ml/60 sec = 1 liter/minute = 0.0353 cu ft/min

The accuracy of your reading will depend, to some extent, on the amount of flow. If the flow is too fast, you will not be able to anticipate the graduate reading accurately and will not be able to signal your assistant at exactly the correct time.

Don't let all of the cautions scare you off. A few tries and you will get accustomed to your setup and know what to expect. If you anticipate a great deal of this type of thing, it might pay you to make a permanent setup. For instance, you could use the manometer reading to indicate flowrate. To do this, make a graph of "flow captured in the graduate" vs "manometer reading" as the position of valve F is varied. Then calculate flow in cfm to transpose the curve to represent flow vs manometer reading. With this setup you could simply hook in the instrument under test and read the manometer. But don't forget; your readings will be meaningless unless you lock valve A so that it retains the position used when making the graph.

Equipment list:

1. A pressure regulator to control the pressure supplied to the instrument being tested.
2. A water or mercury manometer.
3. Hoses or tubing of sufficiently large diameter to be of little influence on the instrumentation; particularly the section containing valve A.
4. Valve A across the manometer should be just large enough to give control of the differential; ½" size is adequate for most tests.
5. Six, good, tight-closing valves of capacity large enough not to interfere with the test.
6. A pressure gauge to measure input pressure to the instrument.
7. A graduate; 1000 ml is usually adequate.
8. A large water container in which to submerge the graduate.
9. A flexible hose or a section of bent tubing to place in the container.
10. An air source.
11. A timer graduated in seconds.



Correction

In our November article "Tape Systems," the Missile Impact Prediction System at Vandenberg Air Force Base was described. However, the X-Y recorder shown in the illustration on page 1911 was erroneously identified as a product of Electronic Associates, Inc., of Long Branch, New Jersey. The recorder is actually the Model 3010 of another manufacturer of X-Y recorders—Milgo Electronic Corp., Miami 47, Fla.

Process Control Systems

FRED D. MARTON, Instruments Publishing Company

FRACTIONATING COLUMN INSTRUMENTATION BY ELECTRONIC SYSTEM

A narrow-cut fractionating column (or bubble tower) is distinguished by a large number of trays, affording a means of separating hydrocarbon compounds with differences in boiling point of as little as 15°F. Being essentially a heat exchanger, it is subject to inherent thermal lags, more so than a conventional fractionating column. The rate at which such columns come to equilibrium after a load change or a disturbance is extremely slow.

There are eight independent variables, seven of which should be controlled, leaving the eighth (composition in feed stock) uncontrolled.

The seven are:

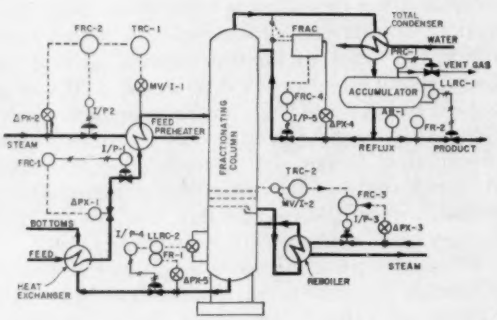
1. Rate of feed to the tower.
2. Temperature of feed.
3. Tower temperature.
4. Tower pressure.
5. Rate of reflux.
6. Rate of product outflow from tower (overhead).
7. Rate of bottoms flow from tower.

The system shown uses electrical controller elements, but is only one method of control that gives satisfactory service. Other combinations and methods may be more satisfactory for other conditions.

Rate of feed is the first variable which needs control. Stable control requires absolutely constant rate of charge in the tower. Controller FRC-1 measures the flow in the feed line through differential-pressure transmitter ΔPX-1 and controls the movements of a double-seated valve via a current/pneumatic converter I/P-1 before the feed reaches the column.

Temperature of feed, the second variable in the system, is controlled by steam to the heater. In this cascade system, temperature recorder-controller TRC-1 senses the temperature in the line from the heater to the tower by a millivolt-to-current transmitter (MV/I-1) which produces a 4-to-20-ma signal. This sets the control point of the steam-flow recorder controller FRC-2, which controls a single-seated control valve in the steam line to the heater through current-pneumatic converter I/P-2. FRC-2 receives its primary signal from an orifice via differential-pressure transmitter ΔPX-2.

Tower temperature control, the third variable can be exercised best when the primary element (filled bulb or thermocouple) is located at the point in the column where a minimum change in composition causes a maximum change in temperature. Hence the sensors should not be located at top or bottom. As the "best" point varies with the percentage composition, the tower is usually equipped wih several bosses for insertion of thermowells at various locations.



Temperature controller TRC-2 which receives a signal from millivolt-to-current transmitter MV/I-2, does not operate the control valve in the steam line directly. It transmits a control signal to cascade flow recorder-controller FRC-3.

FRC-3 also receives a 4-to-20-ma signal from flow transmitter ΔPX-3. The control signal FRC-3 produces is an electric signal which is converted to a pneumatic signal (0-15 psig) by current-pneumatic converter I/P-3 for valve actuation.

Tower pressure, the fourth independent variable, is controlled indirectly by throttling the vent gas line from the accumulator via pressure recorder-controller PRC-1.

Rate of reflux, is the fifth variable. Reflux is controlled by recording controller FRC-4, via a control valve in the line from the accumulator to the top of the tower. Control of the flow rate from the top-of-tower temperature only would be inadequate; good control of the reflux rate from this variable would at least require a second measuring point in the mid-section of the tower.

A Fractionator Reflux Analog Computer (FRAC) receives three signals—reflux flow (from a flow transmitter ΔPX-4), and differential temperature between the overhead vapors and the liquid reflux. It calculates the optimum reflux rate and the resultant output signal is fed to FRC-4.

The sixth variable in the control system is the *rate of overhead flow from the tower*. Overhead product is pumped out of the accumulator. While part of the product is recirculated through the tower, the main stream is throttled by a double-seated control valve receiving its signal from the liquid-level controller LLRC-1, which gets its impulse from the level in the accumulator. An averaging differential-type level instrument is preferred over a float type.

Flow of bottom product is controlled from the level in the reboiler, using an averaging differential-type level instrument (same as used for controlling top flow). This is shown as LLRC-2. It controls a valve in the bottoms flow line via a current-pneumatic converter I/P-4. FR-1 is the bottoms flow which records on LLRC-2.

An analyzer AR-1 is used to record the composition of the overhead product. This is used as a basis for adjustment of the tower conrtols.

Other instruments with no control function can (1) record or indicate temperatures of other points within system, (2) record and integrate rate and quantity of flow of the end product (FR-2), and (3) do the same with the bottoms product (FR-1).

General procedure is to establish controls so that each independent variable is controlled, and sufficient flexibility is allowed for variations in feed and specification of product. It is necessary to control either directly or indirectly the rate of flow of all streams (material or energy) to or from the column and the composition of the desired product. The point of control should be where the volume of material is large. The control instruments should be selected and located so that the speed of their response is at least equal to the rate of change in feed, but not greater than the response of the stream being controlled.

Source: Minneapolis-Honeywell Regulator Company, Industrial Products Group, Philadelphia, Pa.

HEAT INPUT TO FRACTIONATOR COLUMN CONTROLLED BY PRESSURE-DROP METHOD

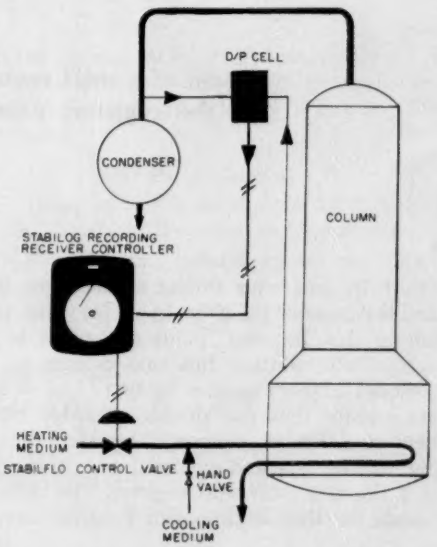
Among the fundamental variables in fractionator control (tower and feed temperature, tower pressure, and reflux, product and bottom-product flow), the tower temperature, or heat input, is the most important. Temperature control can be achieved in various ways.

Operation at maximum capacity is very often the most important consideration in fractionating-column operation. A convenient means of obtaining this objective—in packed, bubble cap, or sieve-type columns—is to control the heat supply to the column on the basis of pressure drop across the column.

In the case of the packed or sieve-type column, the total pressure drop across the column is the combined effect of the resistance of the packing or sieve plates to the vapor and the liquid mass velocities through them. The total drop is representative of the upward vapor velocity through the column. Maintaining the proper pressure drop assures operation of the column at the theoretical velocity for which it was designed. Maximum utilization of equivalent plates is insured.

In the case of the bubble-cap column, the total pressure drop across the column is made up of the resistance of the static head of lquid on all the plates, plus the combined drop through the tray openings and trim, considered as orifices. Maintaining the total drop at proper level eliminates the efficiency-reducing effects of carryover and priming.

The system shown is used by Dow-Corning Company in a pilot-plant fractionator producing chlorosilane and silicones. Correct vapor velocity is achieved by measuring the pressure difference between the overhead line to the condenser and bottom of the column with the aid of a differential-pressure transmitter (d/p). A receiver-controller controls a control valve in the heating-medium input line. The heating medium is Dowtherm liquid or Dowtherm vapor, which is fed from a central gas-fired source to the column.

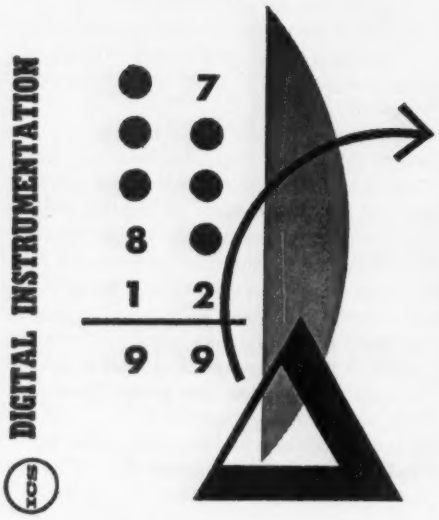


(The hand-controlled cooling medium affords a means of a fast change-over to another charge in this pilot operation.)

Other controls on the column (feed temperature, reflux rate, etc.) are conventional.

Equipment used: d/p cell transmitter (with provisions for inert-gas purge where required by the process), Type 13A. Model 40 Stabilog recording receiver controller with proportional and reset mode (or equivalent small case Model M/53-58 Consotrol combination); Stabilflo control valve with radiator bonnet (for Dowtherm vapor), or packless Teflon gland (for Dowtherm liquid).

Source: The Foxboro Company, Foxboro, Mass.; also Application Engineering Data 282-14.



Shift-Register Logic

ROBERT W. BROOKS, Computer Control Co.

Logic of a shift register is developed for one stage in the register, using dynamic logic techniques.

TAKE any binary number (say 111 = 7) and shift its bits one column left. You have doubled the number (1110 = 14). This is the same as shifting the "decimal" point one place to the right. Similarly, shifting bits one column to the right divides a binary number by two (11.1 = 3.5). A shift register thus can double or halve binary numbers it holds in storage. This doubling, or halving, can be repeated over and over, if desired.

Fig. 1 shows a 3-bit shift register. The different commands the shift register can be given are:

1. Write in Parallel (W_p)
2. Shift Left (S_L)
3. Shift Right (S_R)

Write in Parallel

When this command exists, each stage accepts the new bit presented to it from the source, and the register holds the new number. This is one way that a number is brought in to the shift register. Once it is in the register it can be moved either to the left (doubled) or to the right (halved).

Shift Left

In shift left, the bit stored by each stage is shifted one stage left—to the higher-order column. For example, stage N receives the contents of the N − 1 stage when the command shift-left exists. This doubles the number stored in the shift register.

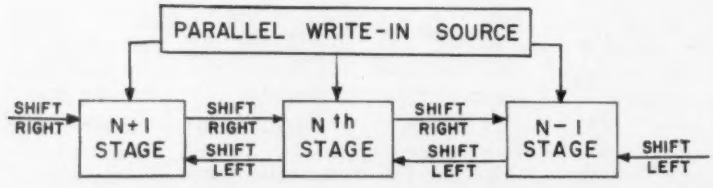


FIG. 1. STAGE N can receive information from either the N−1 stage, the N+1 stage, or from a number source (read in parallel).

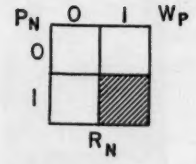


FIG. 2. IN READ-IN, R_N becomes 1 only when both W_P and P_N are 1.

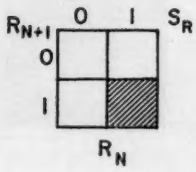


FIG. 3. IN SHIFT right, R_N becomes 1 only when both S_R and R_{N+1} are 1.

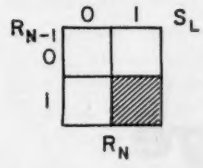


FIG. 4. IN SHIFT left, R_N becomes 1 only when both S_L and R_{N-1} are 1.

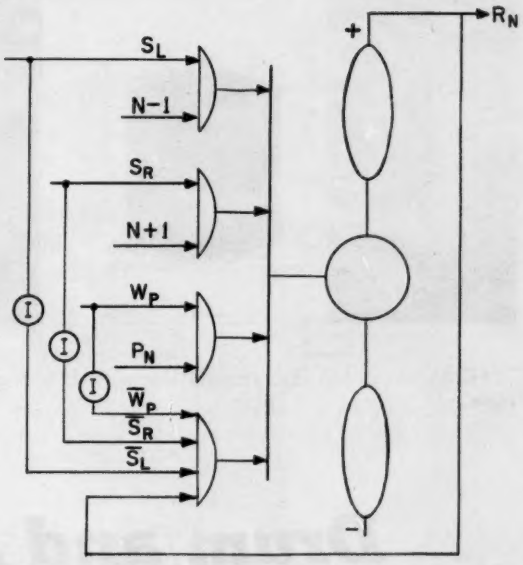


FIG. 5. AND GATES implement equation (7). The ovals are 1-μsec delay lines, so R_N occurs 1-μsec after the inputs occur.

Shift Right

In shift right, the bit stored by each stage is shifted one stage right—to the next lower-order column. Stage N receives the contents of the N + 1 stage. The number in the shift register is now one-half the value before this shift.

The operation of the shift register can be examined by observing the action of one stage when it receives these commands.

Fig. 1 shows the N stage of a shift register and the stages adjacent to it. Each stage can hold one bit of a binary number. The N + 1 stage holds the bit of the next higher-order column; the N − 1 stage holds the bit from the lower-order column. The letter P represents a bit which is to be entered into the shift register from the write-in source; P_N is the bit in the column which is aligned with the N stage. The N stage receives P_N when W_P (Write-in-Parallel command) exists.

The contents of stage N is R_N. There are three sources for R_N—(1) from the write-in source, (2) from the adjacent higher-order stage and (3) from the adjacent lower-order stage.

Shift Logic

If the source is P_N (the write-in source), then

$$R_N = W_P \cdot P_N \qquad (1)$$

This says that R_N exists only when a write-in command (W_P) exists and a bit to be written in (P_N) exists. Note: if W_P exists but P_N is 0, then R_N becomes zero, even if it previously were 1.

Fig. 2 shows the logic chart for symbolic-logic equation 1.

The second source of information (R_N) for stage N is the contents of the N + 1 stage (R_{N+1}). When the shift-right command (S_R) is given, R_N is made equal to the content of the N + 1 stage. This can be written:

$$R_N = S_R \cdot R_{N+1} \qquad (2)$$

R_N becomes 1 only when *both* S_R and R_{N+1} are 1 (Fig. 3). Now there are two conditions for R_N to be 1:

$$R_N = W_P \cdot P_N \vee S_R \cdot R_{N+1} \qquad (3)$$

The third condition follows a shift-left command (S_L):

$$R_N = S_L \cdot R_{N-1} \qquad (4)$$

Again, S_L and R_{N+1} ***both*** must be 1 for R_N to be 1 (Fig. 4).

When any of the three conditions described exist, R_N is 1. That is:

$$R_N = W_P \cdot P_N \vee S_R \cdot R_{N+1} \vee S_L \cdot R_{N-1} \qquad (5)$$

Thus R_N is responsive to any one of three sources.

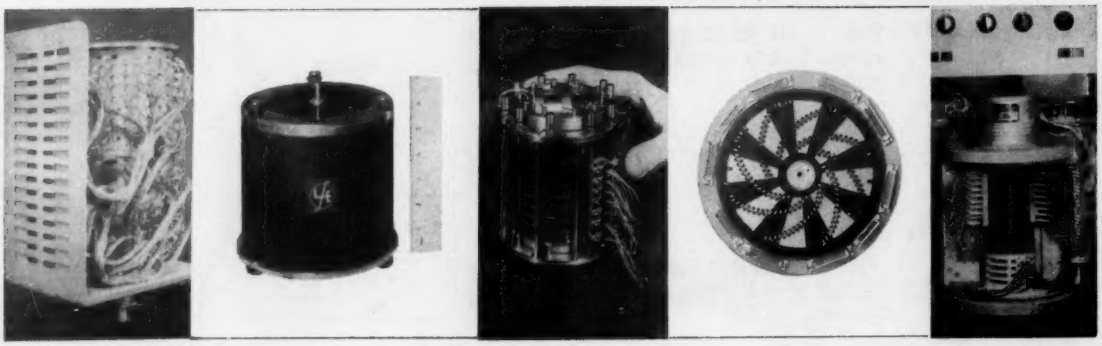
Sometimes none of these commands is given. At these times the information contained by stage N (or any stage) should be retained. This is accomplished by telling stage N to retain its contents during the time that new information is not being brought in—that is, R_N remains 1 if there is no write-in or shift command. This can be written:

$$R_N = R_N \cdot \overline{W}_P \cdot \overline{S}_L \cdot \overline{S}_R \qquad (6)$$

The combined statement for R_N is this:

$$R_N = W_P \cdot P_N \vee S_R \cdot R_{N+1} \vee S_L \cdot R_{N-1} \vee R_N \cdot \overline{W}_P \cdot \overline{S}_R \cdot \overline{S}_L \qquad (7)$$

A logic circuit that performs this operation is shown in Fig. 5. The four AND gates at the left represent the four terms on the right in equation 7. The OR gate then closes the loop.



TYPICAL drum and disc storage elements. LFE disc memory (second from left) uses Bernoulli separation principle.

Drum and Disc Storage

J. M. GOTTSCHALK*
W. J. WASYLENKO**
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Research Center

This survey of drum and disc recording techniques covers history, techniques (RB, RZ, NRZ-C, NRZ-M) and types.

STORAGE (memory) requirements for most digital computers are:

1. **Capability of storing information indefinitely (in a non-volatile manner).**
2. **Accessibility of information, when called for, with minimum delay (low access-time), and preferably with nondestructive readout.**
3. **Capability of altering or erasing stored data to permit storage of new data.**
4. **Capacity to store a vast amount of information—perhaps 10^8 bits.**
5. **Minimum cost per bit stored.**

Magnetic drums and discs meet most of these requisites. Although their access time is greater than that of cores, these devices are used commonly for the main storage mechanism of most general-purpose digital components. Where information is to be used in a sequential fashion, magnetic tape is used commonly, as in input devices; where smaller access time is essential, the more costly core can be used.

Magnetic Recording

The three essential components of any dynamic magnetic storage device are:

1. **A magnetizable medium with suitable retentivity.**
2. **A write head and a read head (may be the same).**
3. **A means for energizing the write head, and means for converting the read-back signals to a usable form.**

The magnetic *media* most commonly used are iron oxides suspended in a resin binder, or an electroplated cobalt-nickel alloy. The read-write *head* consists of a ferromagnetic core (basically a toroid) with a small gap containing a non-magnetic shim. One or more coils of copper magnet wire are wound about the magnetic core. The core element is mounted in a shell to position the gap close to the magnetic surface. Electronic amplifiers provide the current required to drive the write head and to amplify the signals from the read head to usable levels.

Storing Digital Information

A spot on the surface of the drum or disc is magnetized for each bit of information to be stored.

Any of several techniques can be used for recording binary digits. Four of the most representative methods are shown in Fig. 2, which shows tape magnetization for recording the binary number 1001100 by each system.

*Mr. Gottschalk is now with RCA, Advanced Development EDP

**Mr. Wasylenko is now with Remington-Rand Univac.

A. **Return-to-Bias (RB).** The tape is magnetized (biased) to saturation in a direction called minus. Zero binary signals have no effect on the tape, which is left magnetized in its biased (minus) direction. Binary 1 signals are recorded by magnetizing the tape in the opposite (positive) direction. After each binary 1 pulse the tape returns to the bias condition. The number 1001100 would be recorded as shown in Fig. 2A. Note that this method requires a clock to read zeros.

B. **Return-to-Zero (RZ).** The tape is initially in its unmagnetized condition. Binary 1 and 0 are assigned opposite magnetization directions and a pulse is recorded for each bit (Fig. 2B). Return to unmagnetized state occurs after each pulse, and the system is self-clocking.

C. **Non-Return-to-Zero–Change (NRZ–C).** The tape is always saturated in one direction or the other. The direction of saturation reveals the bit recorded. Reversals in direction occur each time the bit *changes* (Fig. 2C).

D. **Non-Return-to-Zero–Mark (NRZ–M).** This differs from NBZ-C recording in that magnetization direction is changed each time a binary 1 is recorded (Fig. 2D). Both NRZ systems require an external clock. NRZ-M is the most widely used in digital recording systems, and appears to offer a good compromise between accuracy, simplicity, reliability, and compatibility. Note that this system involves the least number of flux reversals.

Each *change* in magnetization level on the tape produces an output pulse on readback. The two styles of readback signals are shown in Fig. 3 and 4. Fig. 3 shows the doublet pulse signal developed when reading a binary 1, then a binary 0, which were recorded by the RZ technique (Fig. 2B). The binary 1 signal swings first above, then below, the background level. The binary 0 is reversed; it swings below, then above, the background level. This system is self clocking; each binary bit produces a readback signal. The disadvantage is that the readback signal has a higher frequency content and a smaller readback amplitude than from other recording methods.

The readback signal for data recorded by the RB technique (Fig. 2A) has no 0-bit signal. Only the 1-signal doublet pulse (Fig. 3) will appear—each time a 1 bit was recorded. A 0 bit is presumed when the clock pulse is not accompanied by a readback signal from the tape data track.

The readback signal shown in Fig. 4 is from a binary 1 and 0 recorded by the NRZ-C technique. A readback pulse is present only when the binary bit sequence changes. When a clock pulse is not accompanied by a readback signal pulse, the bit remains unchanged; that is, it maintains its previous value.

The signal shown in Fig. 4 is produced when reading data recorded by the NRZ-M technique. Now each readback pulse means a 1 bit—regardless of the polarity of the readback pulse. When the clock pulse is not accompanied by a readback signal pulse, a bit 0 is presumed.

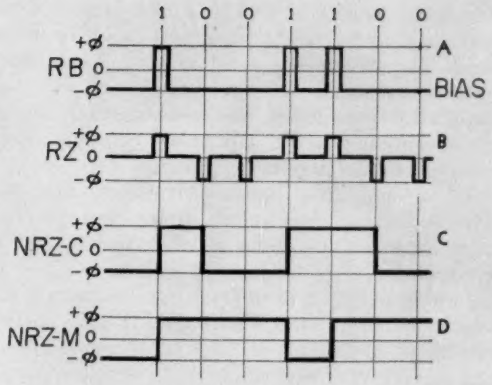

FIG. 2. TAPE magnetization in RB recording, RZ recording, NRZ-C recording, and NRZ-M recording for number 1001100.

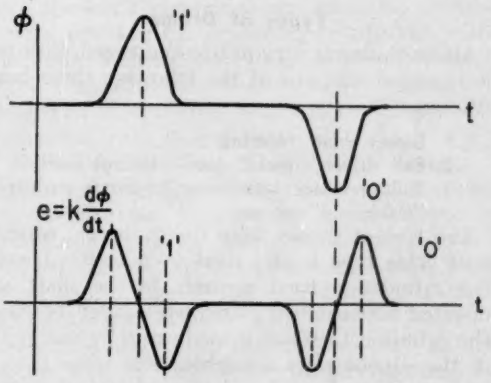

FIG. 3. RECORDED bits and readback pulses using RZ technique.

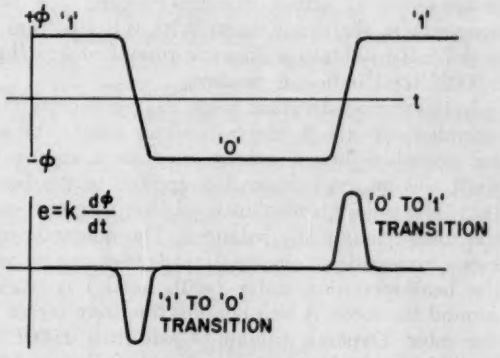

FIG. 4. RECORDED bits and readback pulses using NRZ-C technique. Pulses look the same when reading back data recorded by NRZ-M technique, but here any pulse, regardless of direction, always means a 1 bit.

Magnetic Drums

The magnetic-drum storage device is not a recent invention. In 1900, Valdemar Poulsen, a Danish engineer, was issued U. S. Patent No. 661619 on a device consisting of a rotatable brass cylinder, on

which was wound a steel wire in a uniform helix, and an associated electromagnet or a recording head. The device was used to record and reproduce audio signals. However, as ear phones were required to hear the reproduced recorded "sound," the invention was not a popular recording device until electronic amplifiers appeared.

When amplifiers became available, tape and wire recorders, rather than drums, were successfully exploited for audio-signal recording and reproducing.

Drums and discs came back into the picture during and shortly after World War II as a medium for computer storage. In the early days of this development, magnetic tape was attached to the cylindrical surfaces of wheels. Today, the device is a true-running cylinder coated with a magnetizable medium, such as iron oxide. Electroplated surfaces also are available.

Types of Drums

Although drums vary in size and speed, they can be classified into one of the following three basic structures:

1. **Direct drive, rotating shaft.**
2. **Belt driven, "dead" (non-rotating) shaft.**
3. **Built-in motor type, using shaftless motors or "inside out" motors.**

The earliest drums were direct driven, rotating shaft. This type is still used in noncritical work. The cylinder is fixed securely to the shaft and mounted between two pairs of preloaded bearings. The cylindrical surface is made true by machining off the runout after assembly. The rotor then is dynamically balanced and the cylindrical surface sprayed with the iron-oxide coating. The head-mounting stator then is placed around the drum and the recording heads positioned properly. A drive motor is either directly coupled (or belt coupled) to the drum shaft. With this structure it is difficult to obtain a dynamic runout of less than 0.0002″ total indicator reading.

In the second structure (class 2), the bearings are mounted directly in the cylinder or rotor. The rotor assembly then is axially fixed on a stationary shaft and an axial preload is applied to the bearings. The runout is machined off after assembly and the rotor dynamically balanced. The magnetic surface (iron oxide or electroplate) is then put on and the head-mounting stator (with heads) is placed around the rotor. A belt couples the drive motor to the rotor. Dynamic runout of less than 0.0001″ is readily obtainable because the shaft has a high stiffness with both ends fixed. As there is fear of belt failure, the belt life is constructed to have a life in excess of the bearing life.

In the third structure (class 3), the motor is mounted directly on the drum rotor shaft, usually between the supporting bearings. The structure requires an a-c motor of the squirrel-cage type. With a rotating shaft the armature or squirrel cage is fastened to the drum shaft and the motor stator is built into the head-supporting structure. In dead-shaft construction the squirrel cage of the inside-out motor is pressed into the drum cylinder, and the stator is fixed on the stationary shaft. Both structures are fixed-speed devices, and they usually require a warm-up period to attain thermal equilibrium. This compensates for the rotor heating caused by the direct coupling to the drive motor. This structure is compact and is favored where volume is a limiting factor.

Thermal Stability

The thermal stability of drum storage devices depends on two factors—(1) the physical properties of the structural materials and (2) the maximum temperature differential between the drum rotor and the head mounting. Materials can be selected that have similar coefficients of linear expansion or which can compensate for any non-linear system expansion. Also, the materials can be properly heat-treated to minimize the distortion at the maximum operating temperature-differential.

The temperature difference between the rotor and the head mount produces a variation in the head-to-surface separation. Increased separation reduces the writing ability of the recording head.

Magnetic Disc Storage

A disc is defined here as a device with a slenderness ratio (outer radius/thickness) of 20:1 or higher. Thicker discs are called plates or turntables. Thin discs are preferred if a large number of discs are to be stacked on a common shaft.

The use of a disc plated with a magnetic material is suggested as a storage device in U. S. Patent No. 836,339 issued to P. O. Pederson on November 20, 1906. However, only since the mid-forties have discs received serious consideration as general-purpose memories for digital computers. The difficulty in obtaining discs with sufficient flatness held back the development.

Compressed air escaping from a shroud around the head is effective in maintaining a uniform gap or separation between the head and the disc surface. This form of head-guiding is termed hydrostatic because an external source of pressurized air is necessary. This "hydrostatic bearing" permits discs with large surface runout (up to 0.010″) to be successfully used for recording.

Discs did not gain approval as storage elements until adequate head-positioning mechanisms were developed.

Kingsbury, in 1897, demonstrated an air-lubricating hydrodynamic slider bearing. The load-carrying capacity of this bearing is low; hence the Kingsbury air-lubricated bearing remained a laboratory curiosity for the student of mechanical engineering. However, the Kingsbury air bearing has proved to be ideally suited as a head-flying device.

To maintain a fixed head-to-surface separation, the low load-carrying capacity of this air bearing favorably limits the head loading force to a small value. This separation is held by a dynamic pressure resulting from a shearing deformation of the air (fluid) molecules wedged between the stationary bearing pad and the moving disc surface. The

success of the air-guided head has re-stimulated interest in magnetic disc storage devices, in particular for large-capacity systems.

Air-guided heads are not limited to flat surfaces. Although heads mounted in hydrodynamic bearings were developed to improve the usefulness of discs as storage elements, heads can be air-guided on cylindrical surfaces.

Features which make discs attractive for memory use are:

1. **Expandability by adding discs on a common shaft.**
2. **Higher volumetric efficiency than drums, conservatively estimated at a ratio of 6:1 for medium storage-capacity, higher for large storage-capacity.**
3. **No need for high-precision bearings, nor is a bearing preload required.**
4. **A damaged disc can be replaced; a scored drum requires expensive reworking.**
5. **Simplicity of construction.**
6. **No variable temperature problem (not true of drums having air-guided heads).**

Disc flatness is important in order to increase the pulse-packing density. High-density recording requires head-to-surface separations of the order of 250 microinches or less. To obtain such flying gaps requires discs having a maximum flatness excursion rate of 0.0004″ per inch. Other specifications for the disc *substrate* includes: Surface finish of 15 microinches or better, ease of plating, nonmagnetic, dimensional stability, and low cost. Disc materials now meet these specifications; however, cost must be reduced substantially to attain commercial feasibility.

Fig. 5 shows a typical head-disc memory constructed at the Burroughs Research Center. It has its head mounted in a gimbal, which in turn is fastened to a pivoted arm, or head-loading bar. The head is loaded by placing weights on a rod attached to the loading bar. The ratio of the weight to the head force is 6:1. With a head-loading force of 0.7 pound and a surface speed of 950 inches per second, a 500 millivolt peak-to-peak readback signal is obtained, at 500 ppi NRZ (on a cobalt-nickel plating 0.00022″ thick having a coercive force of 650 Oersteds). A signal-to-noise ratio of at least 70:1 was measured. The noise level is sufficiently low to be ignored.

To improve on this performance, the head was redesigned using a better ferrite for core material and a smaller gap. This, together with increased head loading for closer spacing, and thinner platings for better high-frequency operation, has made it possible to obtain pulse-packing densities in excess of 1500 ppi with readback signals of 30 millivolts peak-to-peak or better.

Heads can be shifted to serve a number of tracks; however, the access time increases by the time required for head shifting.

To improve the access time of a disc memory, it is possible to limit the area serviced by one head to an annulus on the disc, thereby limiting head travel. In such a multiple-head structure (Fig. 5), each head services a number of annular tracks covering a band equal to the separation of adjacent heads. The entire multiple-head structure is shifted by integral track widths to position any one head on a desired track. Only one head can be brought over a specified track at a given time.

FIG. 5. DISC and multiple-head structure.

The multiple-head assembly of Fig. 5 contains 10 heads, and the entire assembly can be positioned in ten discrete track locations by a combination of electromagnets and a spring return. This gives a total capacity of 100 tracks, the track density being 32 per inch in this design. Disc diameter is 13.25″ and thickness 0.260″.

Magnetic discs will continue to play an important role as large-scale memory devices for data-processing applications. As recording density increases, the cost of storage per bit will decrease.

Discs working from the 60-cycle power line have an optimum access time of 17 milliseconds, provided no head-shifting is required. It is possible to obtain fairly fast shifting mechanisms at reasonable cost, provided the accuracy for track-positioning is not too demanding.

As in any other problem, the design of magnetic-disc memories involves a compromise between performance and cost. The high-performance features are desirable where discs are to take the place of main memories in small or medium-sized machines. However, in places where discs are considered as replacements for magnetic tape, the high performance may not be required.

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THE MODERN ENGINEERING DEPARTMENT has adequate data computing, analysis, and recording instrumentation.

Computer Uses

A wide variety of process and mechanical engineering problems are being solved on general-purpose computers. The following reports a representative sampling of the work that is being done in the chemical and mechanical fields on Bendix G-15 Computers.

Dow Chemical Co. (Texas Div.)

Process engineering design of heat exchangers, distillation equipment, fluid pipe lines, and process simulation are the major areas of work assigned to the computer. Time breakdown shows 50% process equipment design; 20% production trouble shooting and efficiency tests; 10% general engineering including piping and electrical; 5% research data evaluation; 15% miscellaneous single problems.

Standard Oil Co. (Ohio) Research Dept.

The computer is operated on an open shop basis and supports 150 technical personnel. Computer time is divided 10% for satellite tracking, 30% for statistical analysis, 10% for material balance calculations, and 50% for one-shot programs—process simulations, system models, predictive studies. Statistical programs are most widely used, but one-shot programming has been of greatest value. The computer is used primarily as a research guide and is particularly useful in a screening analysis before research work is begun.

Standard Oil Co. (Ohio), Mfg. Dept.

The computer serves approximately 250 technical personnel in the Refinery Engineering, Management Methods, and the Operations Staff Units, on an open shop basis. Major areas of work include thermodynamics and yield studies. Ten percent of computer time is devoted to production problems—enthalpy, latent heat, gasoline blending, multiple linear and non-linear regression analysis—and 10% for statistical work. The remaining 80% is used for one-shot development programs.

E. I. DuPont De Nemours & Co., Inc.

The computer group consisting of three engineers and four technologists, serves a technical staff of approximately 110. Major areas of work are data reduction, statistics, reactor design, and economic evaluations. Computer time percentages are 60% data reduction—involving conversion of observations made in a Chemical Semiworks to performance data such as conversions, yields, etc.; 15% statistical; 5% one-shot programs; 20% miscellaneous.

Sun Oil Co.

Computer group supports a technical staff of 100 people. Reservoir engineering, mechanical design, and production service engineering are the major areas of work for the computer. Production problems include reservoir performance simulation, vapor-liquid equilibrium, casing design, evaluation of geophysical velocity functions, reservoir material balance calculations and economic analyses.

Allis-Chalmers Manufacturing Company

Nuclear reactor problems—mainly heat transfer, fluid flow, reactor physics, reactor hazards analysis, and the work-up of experimental data on heat transfer and fluid flow. Time: 80% for one-shot and standard engineering programs, 20% for data reduction.

Foster Wheeler Corp.

Problems include thermal stress analysis of orthogonal multianchor piping systems, pulsation damper design, distillation tower design, plate-to-plate calculations, design of steam generators, beam stress analysis, cooling-tower performance calculations.

Experiment Inc.

Problems: Fluid-flow analysis, chemistry of fuels, data reduction, design analysis, and miscellaneous engineering calculations. Time: 20% fluid-flow analysis (pressures, temperatures, drag, thrust); 40% chemistry of fuels (flame temperatures, specific impulse, combustion efficiency); 15% data reduction (burner, turbine and jet performance); 15% design analysis (configuration requirements for nozzles and inlets); 10% miscellaneous calculations (trajectories).

Rohm & Haas Company

Data reduction occupies 30% of the computer's time; 20% (each) for statistical analysis, solution of various systems of differential equations, and one-shot research problems. Remaining 10% is spent in spectroscopic analysis.

The Lummus Company

Most problems are concerned with the design of process plants and process equipment (90%); 10% for mathematical routines.

Worthington Corporation

Critical speeds of slender shafts and reciprocating compressor analyses occupy 85% of the computer's time; 10% for one-shot engineering gas-log tables, and 5% for statistical calculations and management decision-making.

Unit Structures, Inc.

Stress analysis of beams and three-hinged arches comprise 75% of the computer's work; 15% for cost estimates and 5% each for price quotation calculations and special problems.

Acoustica Associates, Inc.

Evaluation of equations over various limits, curve fitting, plotting of various distributions and regression lines, and the generation of tables for data reduction.

National Research Council of Canada, Ltd.

Computer time is divided 10% statistical (curve fitting); 20% data reduction (wind tunnel, flight test, heat transfer tests, spectro-photometer readings, auto-correlation and power spectrum of water wave records); 40% engineering (propeller or fan design, gas turbine cycle); 30% scientific (crystal structure theory).

Bendix-Pacific Division

Calculations of radar and sonar beam patterns. The computer group works closely with the facility's analog group doing calculations of Bode and Nyquist curves as well as transient responses. Also complex arithmetic assist in check cases and transfer-function calculations for guidance and servo systems. Time: 60% one-shot engineering problems, 20% data reduction, 15% statistical, 5% table generation.

Canadian Pratt & Whitney Aircraft Company, Ltd.

Performance of components, engines, and optimization programs. Time: 50% stress analysis, 20% performance calculation, 10% aerodynamics and thermodynamics, and 20% data reduction and miscellaneous.

ACF Industries, Inc.

Basic work is solution of standard deviation of molded plastic parts for production of numerical tool-control tapes. A DDA accessory and graph plotter facilitate solution of heat transfer problems. Time: 20% for one-shot engineering problems, 10% for stress analysis, 20% for data reduction and 50% for numerical tool control tapes.

Bucyrus Erie Company

Design of booms of latticed construction used for dragline, crane work, and clamshell work. "Only when a computer is used is the complete calculation of a boom feasible."

The Magnavox Company

Time: 5% for statistical work, 10% stress analysis, 10% data reduction of field and experimental data, 65% for one-shot problems, and 10% miscellaneous.

Eclipse-Pioneer Division

One of the three G-15's is allocated to the problems of instruments and components in the Electrical Instrument Laboratory. Computer time: 45% electro-magnetic resolver and synchro chain analysis and optimum design of magnetic components; 30% gear analysis; 10% determination of test points for navigational computers and error analysis of coordinate converters and other computer circuitry; 15% mechanical reduction devices, cam computations, special statistical analyses.

Curtiss-Wright Corporation

Computer problems: structural analysis, vibration analysis, noise studies, control and performance studies, aerodynamic analysis, dynamic analysis and miscellaneous mathematical solutions. Computer time: 75% stress and vibration analysis, 5% data reduction, 10% one-shot engineering, 10% statistical.

John Deere Tractor Research and Engineering Center

Major programs are gear design, crank-shaft deflection etc.

Bendix Products Division

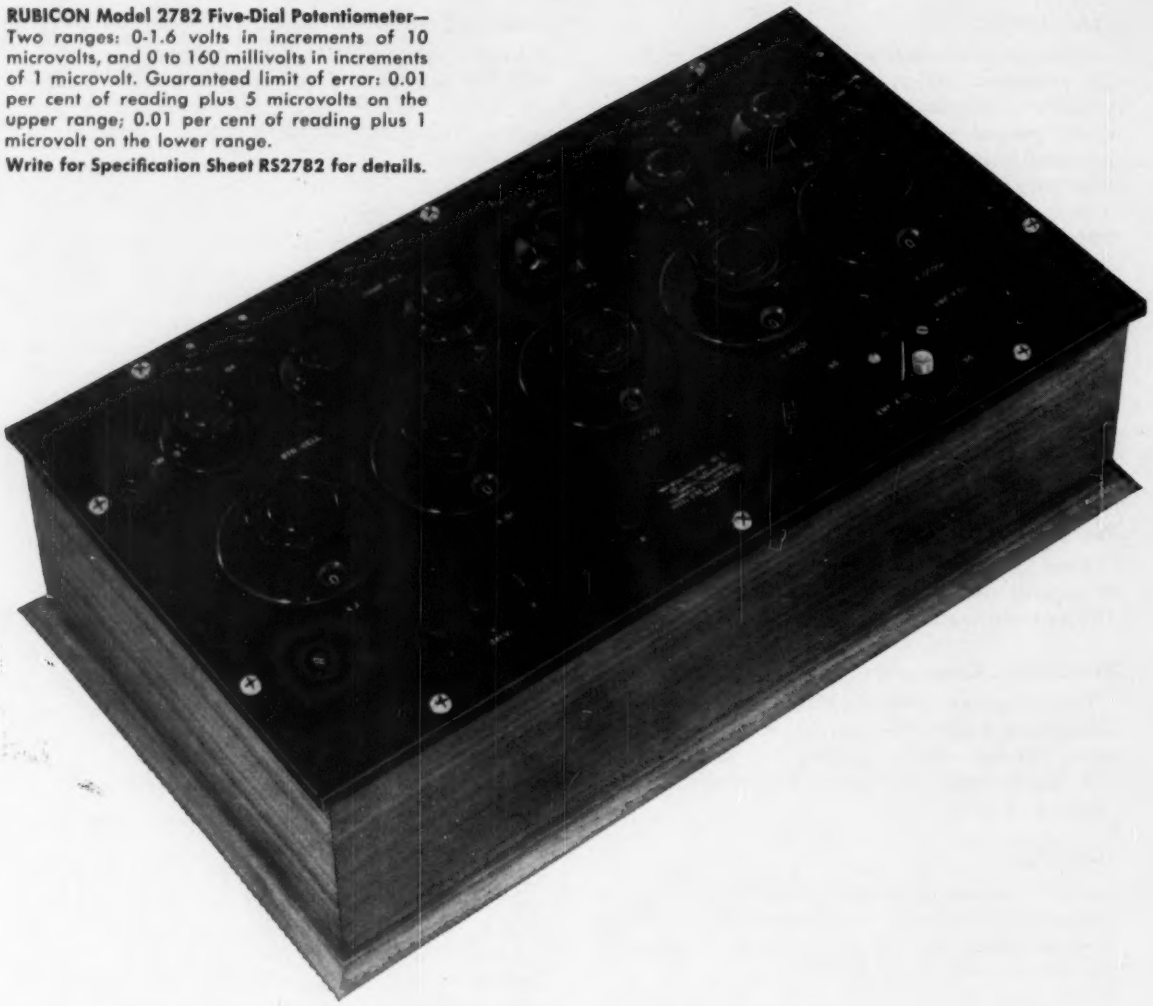
Stress analysis, vibration and motion studies, data reduction, heat transfer, cam design and numerical control.

Fellows Gear Shaper Co.

Design of gear-shaper cutters, shaving tools, master gears, cams and cam cutters.

RUBICON Model 2782 Five-Dial Potentiometer— Two ranges: 0-1.6 volts in increments of 10 microvolts, and 0 to 160 millivolts in increments of 1 microvolt. Guaranteed limit of error: 0.01 per cent of reading plus 5 microvolts on the upper range; 0.01 per cent of reading plus 1 microvolt on the lower range.

Write for Specification Sheet RS2782 for details.



HOW "ACCURATE" SHOULD A POTENTIOMETER BE?

Potentiometer accuracy claims can be misleading. They can sometimes be based on one-shot tests made under ideal laboratory conditions. Their validity can depend on the method used to establish limits of error.

The real measure of potentiometer accuracy is not how little the instrument drifts from set resistance values at one given moment, but how *long* it will remain faithful to its certified calibration. Only a potentiometer that gives consistently stable, reproducible results over its entire life can deliver the performance you pay for.

Such a potentiometer is the one shown above, our Model 2782. It incorporates refinements in potentiometer design that provide high stability and long-term accuracy. For example, the use of high-stability 10-ohm resistors in the first dial and 1-ohm resistors throughout the four lower dials insures permanence of calibration. And because the switch of the first dial carries no current at balance, its contact resistance can introduce no error of measurement. Many other design innovations help maintain the potentiometer's *realistically* high accuracy. Still, the instrument is priced below comparable potentiometers offering far less.

All Rubicon instruments are the product of a long tradition of engineering excellence and exceptional craftsmanship. The complete line is available through any of the Honeywell branches throughout the nation.

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Standards and Management

C. E. WHITE, AVCO R. A. D., Wilmington, Mass.

CHARLES E. WHITE has been in charge of the Laboratory Measurements Section of AVCO RAD (Research and Advanced Development), Wilmington, Mass., since 1956. He planned, staffed, equipped, and supervised the primary and calibration standards facilities (reported in detail in I&CS). Prior to his present position, he was with: USN Medical Research Laboratory (1952-56); Electronics Div. of Electrical Design Dept., Electric Boat Company (1947-51); RCA Service Company (1936-46); Western Union Telegraph Company (1928-36). He has also been a consultant in acoustics and structural planning. He has authored many technical papers on instrument accuracy, instrument environmental effects, reliability/quality programs, measurements techniques, noise measurements, etc. He has a BSEE degree from New York University, and MSEE from University of Connecticut.

His professional associations include: Institute of Radio Engineers (Chairman Merrimack Valley Sub-section); Acoustical Society of America; Audio Engineering Society; Society of Motion Picture & Television Engineers. He is a registered Professional Engineer in Connecticut and Massachusetts. Appointed member of International Scientific Radio Union (URSI), member of USA Commission I—Radio Standards (National Academy of Sciences).

Chas. is 50, married, has one daughter.

A SURVEY IN 1959 of standards activities[1,*] maintained by government contractors revealed:

1. There is a lack of centralized management control over calibration programs.
2. There is a general lack of traceability of calibration to the National Bureau of Standards.
3. Industry is not generally aware of the capabilities of NBS.
4. There is need for increased accuracy in many fields, to be supplied by NBS.

There is still slight evidence of interest in the deficiencies revealed by the survey. An important step, taken by the Secretary of Commerce in 1958 was to request that the National Academy of Sciences undertake a survey of the Department's activities and make recommendations. A special advisory committee of the Academy in its March, 1960 report[2,**] made recommendations to the Department of Commerce for the National Bureau of Standards which included the following.

1. "The measurements standards efforts be expanded to provide adequate coverage of the nation's standards efforts. A rate of increase of effort of about 15% per year is suggested . . . ."
2. "Directly appropriated funds be obtained for all activities in the Measurements and Standards area that are of broad national interest . . . ."

A second survey[3] was conducted in 1960 to determine in what fields industry feels the need for improved accuracies, and wishes NBS to conduct research. To implement the survey, the first Measurement Research Conference encouraged by the Aerospace Industries Association's Quality Control Committee and the National Bureau of Standards was held at Boulder on May 24-25, 1960. This represented the first time that industry and government faced each other in open session to determine and to substantiate the demands made by industry upon the government's official calibration centers.

Substantiation of accuracy requirements plays as great a part in creating support for Bureau activities

*See I&CS, April, 1960, page 596.
**See I&CS, July, 1960, page 1138.

as demand for services; it is well known that development and product specifications and test procedures quite often are unrealistic because (1) too often an unawareness of state-of-the-art is evident in the extreme accuracies and/or minute tolerances spelled out in procedures, (2) too little analysis has been made of the effect upon the end item of a lowered accuracy or increased tolerance requirment in specifications. This is a function which can be filled capably by any knowledgeable calibration activity.

Another step forward is the increased weight being given standards in the military quality-control program. To prod contractors into more diligent compliance with quality requirements, Air Force inspection teams are conducting an evaluation of contractors' abilities to trace accuracy to NBS.

There is evidence that several large corporations are being nudged along the path of standards control at the corporate level. In process of formation at the present time, also, is a training program at George Washington University at graduate level to supply qualified personnel capable of staffing standards activities.

Management Demands Justification

All standards activities are under the constant scrutiny of cold, practical, profit-motivated management eyes. The administration thus must be able to present its case for controlled environment, a high level of competency in personnel, the need for professional development in the several fields of measurement, and last but not least the distinct probability that the activity will enhance the company's ability to produce an end-item of highest quality.

Proof of the last statement is extremely difficult. Constant communication between the administration and management will establish the justification for each phase of the standards operation. Most important, the operation is elevated to the respected position it deserves when its capabilities have been proven.

A good deal of soul-searching is required in the determination of fields and ranges of calibration activity. The level and extent of operation depends on many considerations—number of units subjected to cyclic calibration, comparative costs of calibration within the company or at a remote service center, extent of loss-time encountered by cycling through a remote agency. The degree of financial support from management, and the extent of the directive from management to initiate and carry on the activity contribute largely to arriving at a satisfactory solution.

The administration of a standards activity can obtain help in answering management's questions. They may consult with the Bureau of Standards, contact existing industrial laboratories, or search the technical literature.*

Within each industrial organization there is a good, selfish reason to encourage a standards activity. By the very nature of the activity, participants are aware of the state-of-the-art in the fields for which they claim proficiency. An awareness of the state-of-the-art in measurements fields is an asset that few industrial organizations have outside their standards laboratories. Every standards activity finds itself employed as a consultant by engineering standards and specification groups, as well as the development areas. In addition, the activity often serves to acquaint research people with the capabilities of measurements in fields contiguous to their own, but in which they have no great proficiency.

Management also should recognize that the second phase of development in standards activity is the seeking after further knowledge, the search for new or improved techniques, in research into new standards which have application locally, or in development or invention of new devices or instrumentation related to the measurements fields which are of interest to the laboratory. "To stand still is to go backwards." A management which discourages an alert standards activity will encourage complacency which in turn leads to a depreciation in quality of work.

Measurement Error Philosophies

In certifying the calibration of measurements standards one is not permitted the luxury of handling cumulative errors on the root-mean-square or exponential basis as is acceptable to our friends in Reliability Engineering. The approach of the standards laboratory to this problem is neither understood nor appreciated by the typical manager involved in quality assurance or control. He may fail to appreciate the fact that certification calls for an expression of the worst possible combination of known errors encountered in the calibration procedure. This can lead to uncertainties in test results because of too small a differential between specified accuracy tolerances in data and the certified inaccuracies of the measuring devices. An understanding of the importance played by measurement systems[4] must be ingrained into any program which spells out test or inspection procedures or specifications.

In a normal industrial operation, the standards/calibration activity usually finds itself in the passive role of defender of measurement accuracy. Were the laboratories to assume the role of *protector* of measurement accuracy, the implication is immediately of a vital force actively engaged in close liaison with planning or specifying activities, and

*INSTRUMENTS AND CONTROL SYSTEMS has been emphasizing calibration and standardization for the past two years.

continually exercising surveillance over instrumentation employed to determine performance characteristics of end-items. It is this role which must be assumed by the standards/calibration activities of the future.

Once this role of protector of measurement accuracy is assumed, recognition will be accorded the activity. That factor which should be jealously observed by all standards/calibration activities is that there can never be any subversion of accuracy by pressure of industrial needs. A truly quality-conscious management does not tamper with accuracy —an uneducated or dishonest management might be tempted.

Extension of Services

A standards activity might desire to share the laboratory's capabilities, on a fee basis, with other companies in which it is impractical or uneconomical to establish standards activities. This must be approached cautiously. Once approved by management, the laboratory must retain control over the furtherance of the sales efforts, first to affirm that services rendered outside the company are on a profitable basis, and second to control the effort in order not to overload the personnel and contribute to a lowering of quality because of the profit-motif.

I have no knowledge of a standards laboratory which is self-supporting. Consequently management must be educated to the extent of realizing that support from within the company must always be forthcoming. Profits from without should serve only to supplement the company's contribution.

Level of Standards

Within many corporations, one can find many calibration activities, each operating as an independent entity. Seldom does there exist liaison of any sort between these laboratories. This represents a deplorable waste of space, facilities, and manpower. Alert managements are becoming aware of the need for:

1. Establishing surveillance over all laboratories.

2. Combining and centralizing seldom-used functions.

3. Establishing a standards activity under direct corporate control and possibly at a centralized geographical location. This function serves two purposes; first—the perfectly understandable one of reducing corporate expenses and supplying high-level standards accessible to all corporate divisional laboratories; second—a reduction in loss-time to the corporation of expensive instrumentation waiting for certification at the heavily loaded National Bureau of Standards. In turn, reduction of the load of low-level calibration work at the Bureau permits more attention to measurement research, vitally essential to the nation at the present time.

It is heartening to realize that the beginning of 1961 saw at least four corporations approaching the problem of centralized standards with a firm step. Disturbing elements in the picture are the lack of trained personnel and the long lead-time required for establishment and operation of the highest level standards laboratory.

Given an open, receptive mind on the part of management, the conscientious standards activity with proven capabilities has a direct challenge to establish its future position. It must learn to question improper procedures, unattainable specifications, and unreasonable or unjustifiable demands for accuracy. Conversely it must fight to push back the obstacles arising from state-of-the-art deficiencies by its own research work, and by its support of the National Bureau of Standards. This all leads to one goal—products of highest quality.

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4. A. G. McNish, "Propagation of Error in a Chain of Standards" Standards Conference-NBS, Boulder, June 22, 1960.

Abstracts from paper presented at 1960 Conference, Standards & Electronic Measurements, Boulder, Colo.

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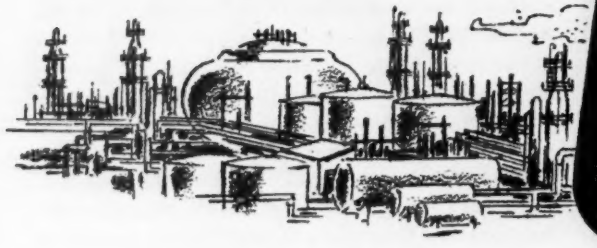

Take accurate temperature-millivolt measurements wherever you go—laboratory, plant or field—with the rugged, compact, portable "MiniMite". Moderately priced, the "MiniMite" (null-balance potentiometer pyrometer) weighs just 3½ lbs., measures just 4″ x 5″ x 6″, provides ¼ of 1% of scale accuracy with a long 23.6″ double range scale. Widely spaced scale graduations facilitate easy, accurate reading. A standard flashlight battery provides standardization.

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Connected to a thermocouple, the "MiniMite" provides accurate temperature indication, anywhere. It is used for standard checking and calibrating procedures. Automatic cold-junction compensation is built-in.

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An adaptation of the "MiniMite", called the Airline "MiniMite", is made to quickly check dynamic performance characteristics of jet engine exhaust temperatures, E.G.T. spread or average and calibrate cockpit indicators. It also can be used as a source of variable dc millivolts.

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Range Scales for the "MiniMite" can measure temperatures from minus 450°F. to plus 3200°F. with all standard thermocouple materials, including various Platinum-Rhodium combinations. Many millivolt scale ranges are available. The double range scales are available with two different thermocouple calibrations, combinations of a temperature and millivolt range, or a single temperature or millivolt scale.

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FIG. 1. **PHAZOR** phase meter Model 200A measures tan θ directly.

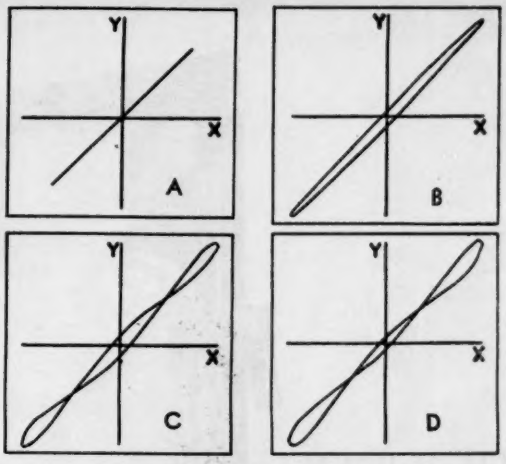


FIG. 2. **LISSAJOUS** patterns.

Phase Shift Measurements

RAYMOND ROTHSCHILD
Industrial Test Equipment Co.

MEASUREMENT of small phase angles is important in current transformers, potential transformers, computing amplifiers, computing transformers, resolver systems, etc.

Few instruments can perform phase measurements accurately. Some instruments employ the principle of measuring phase by noting the respective zero-axis crossings of the reference signal and the signal of unknown phase. Considerable error can be introduced by this method if one of the signals contains noise and harmonic components. This is especially true if the noise or harmonic peak occurs in the vicinity of a zero-axis crossing. Ambiguities that can arise are shown in Fig. 2.

Fig. 2A shows the lissajous figure resulting from the signals $y = \sin \omega t$; $x = \sin \omega t$ (two voltages with zero phase-shift).

Fig. 2B shows the lissajous figure resulting from the signals $y = \sin (\omega t - 3°)$; $x = \sin \omega t$. A 3° phase shift has been introduced in the y signal, resulting in the conventional ellipse.

Fig. 2C shows the lissajous figure resulting from the signals $y = \sin \omega t + 0.1 \cos 3\omega t$; $x = \sin \omega t$. That is, 10% 3rd-harmonic distortion has been introduced in the y signal.

Fig. 2D shows the lissajous figures resulting from the signals $y = \sin (\omega t - 3°) + 0.1 \cos 3\omega t$; $x = \sin \omega t$. A 3° phase shift of the fundamental component has been introduced in a y signal containing 10% 3rd-harmonic distortion.

The phase shift is discernible in Fig. 2B (the case of zero distortion), but C and D show that the determination of phase shift in distorted signals can become ambiguous.

Two voltages are required in order to measure phase —a reference voltage and a voltage whose phase is to be measured with respect to the reference. The voltage of unknown phase can be resolved into two basic components at right angles to each other—an in-phase component (in phase with the reference), and a quadrature component (90 degrees with respect to the reference). Any instrument which can separate components in this manner can be used to measure phase. Fig. 1 shows such a meter, which can be used to measure these components and at the same time eliminate the effect of noise and harmonics.

The principle of operation is based on a precision multiplying device. The multiplier output is proportional to the instantaneous product of the input signal and the reference signal. A d-c meter accepts the output from the multiplier and produces a deflection proportional to the time average of this instantaneous product. If the input signal V is A sin $(\omega t + \theta)$, and if the reference signal (V_R) is B sin ωt, then the meter deflection $D_1 = \int AB \sin \omega t \sin (\omega t + \theta)\, dt$, or $D_1 = kAB \cos \theta$.

This is similar in operation to an ordinary electrodynamometer-type wattmeter, which uses a current coil and a potential coil.

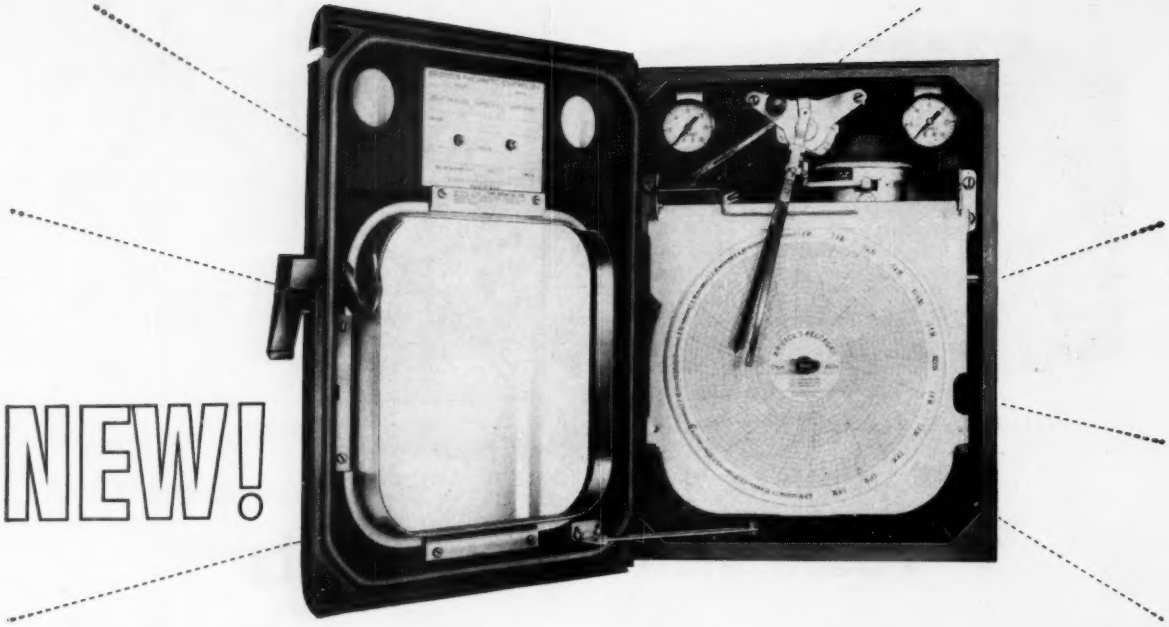
By using a built-in phase shifter which is capable of shifting the input signal 90° the phase between two signals can be measured (irrespective of the magnitude of the signal) because with an input phase shift of 90° the meter deflection would be proportional to the sine of the phase angle between the reference and input voltage (or quadrature component). That is, after 90° rotation the signal D is:

$$D_2 = kAB \sin \theta$$

By taking the ratio of these two signals:

$$D_1/D_2 = kAB \sin \theta / kAB \cos \theta = \tan \theta$$

Thus we have a method of measuring phase shift between two signals irrespective of the magnitude of the signals. The accuracy of measurements is generally better than ±1°.



Bristol Series 532 A/D* pneumatic recording controller is outstandingly SIMPLE, RELIABLE, and STABLE

- **Simple modular design for ease of servicing**
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Top control performance with maximum simplicity plus standard Bristol precision measuring elements—those are the key features of the Bristol Series 532 Recording Controller. The 532 uses the same renowned elements that have earned such a reputation for accuracy and dependability on other Bristol automatic controlling and recording instruments—perfected through wide experience and many years of development.

Self-contained modular design of the control unit speeds servicing. The whole modular unit, consisting of an aluminum casting with working parts made of stainless steel, Ni-Span C, and Neoprene diaphragms, can be removed by taking out only two screws and a link.

The die-cast aluminum instrument case (15¾ x 10¾ x 5¾ overall) presents a streamlined appearance and is completely dustproof and weatherproof.

Write for complete data on the new, versatile, economical 532 A/D. The Bristol Company, 113 Bristol Road, Waterbury 20, Conn., a Subsidiary of American Chain & Cable Company, Inc. 0.46

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CONTROL UNIT CHARACTERISTICS:

PROPORTIONAL BAND: 0-400% continuously adjustable, direct- or reverse-acting.

RESET: 0.1 to 100 repeats per minute.

DERIVATIVE: 0 to 10 minutes derivative time.

AIR PILOT: Non-bleed type.

PILOT CAPACITY: Over 3.0 scfm.

FREQUENCY RESPONSE: Essentially flat to 300 cycles per minute.

TEMPERATURE STABILITY: Less than 0.1% change in the output pressure for 90°F temperature change.

CHART: 8" diameter; wide variety available.

MATERIAL: Aluminum housing; 316 stainless steel internal parts; Ni-Span C feedback element.

RECORDING CONTROLLERS OFFERED FOR:

PRESSURE AND VACUUM: Ranges from full vacuum to 15,000 psi.

TEMPERATURE: Ranges from—100°F to +1000°F.

FLOW AND DIFFERENTIAL PRESSURE: With mercury-type manometer and dry-type differential unit.

LIQUID LEVEL: With bulb unit and mercury manometer and dry-type differential unit.

HUMIDITY: Zero to 100% relative humidity.

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Regulator Station Design for Large Customers

Delivery of large volumes of gas (8 million SCFH) from high-pressure lines to steam plants and other large customers imposes many problems for the gas engineer in the design of regulator stations. This paper covers the design and selection of regulators from the standpoint of stability, speed of response, and vibration.

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Meeting Notice—Thur. May 18, Rio Hondo Country Club, 6:30 PM (dinner); 8:00 PM meeting
Subject: Automation Comes to the Oil Field
Speaker: Mr. Claude B. Nolte, V.P. Barton Instrument Corp.

Presented at Ninth Annual Instrument Short Course, Los Angeles Harbor College, April 13, 1960.

LARGE steam generating plants use up to 8 MMSCFH (8 million standard cubic feet per hour) or more of natural gas flow, with inlet pressures varying from 150 to 500 psig.

In considering control valves for such applications, one basic factor is the *weight* of the fuel being handled. As natural gas weighs approximately 0.05 lb per cu ft, a station handling 8 MMSCFH will, in a 24-hour period, pass the equivalent weight of nearly 100 carloads of coal. It is hard to visualize this, as natural gas is a product not seen or carried around in a bucket, but imagine 4 carloads of coal being pushed through the regulator station every hour.

In addition to the large amount of product *weight*, the product is being handled at high *velocities*. Most control-valve installations of this type are called upon to take pressure cuts at critical or greater pressure drops. This means that the product is being handled at sonic velocities.

The energy dissipation in a reducing station is large. Usually, energy dissipation means heat. However, the gas man is lucky in that gas thermodynamics in regulator stations result in a cooling process. If not, the valve soon would be a melted mass of steel. Incidentally, hydrogen does heat instead of cool under some conditions, and thus presents a problem.

The large weight, the high velocities and the dissipation of energy are a challenge to the control valve. Sometimes it shakes, jumps, squeals and

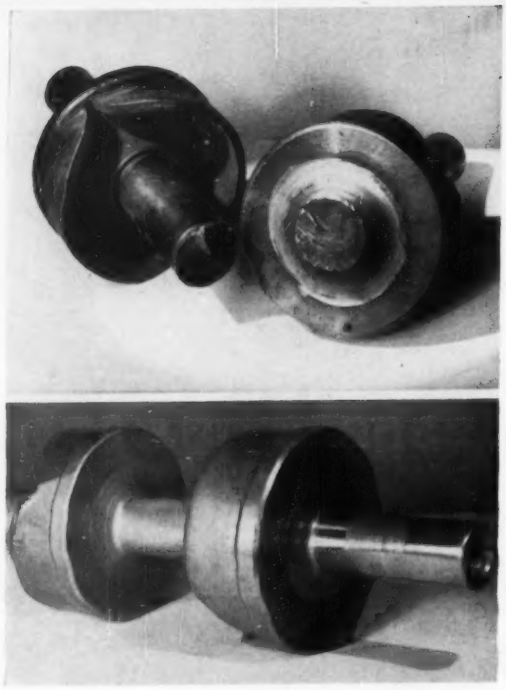


FIG. 1. TWO INNER VALVES that failed because of vibration at natural frequencies.

howls in protest to the life it is leading. This is no place to use marginal equipment. Not only the valve but also the piping design of the station must be given considerable attention because of the high energies involved.

Vibration Spectrum

The protest that the inner valve makes to this mass velocity or momentum of gas flow is in the form of vibrations, including (1) pronounced vertical instability, (2) mechanical vibration, (3) natural-frequency vibration, and (4) aerodynamic vibration caused by the gas flow.

The most damaging effect of *vertical instability* is the resulting guidepost and bushing wear. As this wear progresses, *horizontal vibration* will start and the rate of damage becomes progressively faster.

If the guide posts and bushings are allowed to wear, the impingement of the gas stream on the inner valve can cause horizontal vibration between the posts and bushings. This vibration emits a rattling or howling sound and can eventually result in failure of the guides as the wear rate becomes progressively faster.

The vertical instability usually occurs at 30-60 cps, which is close to the natural frequency of the moving parts of the control valve (the topwork, inner valve, spring, etc.). A vibratory movement of 1/32" amplitude can result in a relative movement between the post and bushing of more than one mile per day!

Most valves have stainless-steel posts with hardened bushings, and the service is such that lubrication is poor. Anything that stops this vibration movement will result in better service life. Hard-surfacing of the posts by Stelliting, or hard chrome plating and the use of hydraulic snubbers, gives a nearly complete answer to the problem.

Solid percent V-port (or V-pup) inner valves have less tendency to jump than the throttle plug or parabolic-style plug. However, both may give trouble on occasion.

The valve is positioned by a pneumatic operator using a compressible medium. This operator is not always capable of dampening all vertical forces in the valve. However, the addition of an oil snubber provides a solid component to dampen out this jumping action.

Natural-frequency vibration is caused by either the inner valve or some component part of the regular station vibrating at its natural resonant frequency. This is distinguished by its sound—a single-pitched tone usually between 3000 and 4000 cps. This frequency is usually very annoying. This type of vibration should be corrected because it is likely to cause fatigue failure of the vibrating part. (Fig. 1).

Heating of the vibrating parts due to natural-frequency vibration often can be noticed. Experience has shown that inner valves fabricated from symmetrically shaped parts are more apt to have this type of vibration. Solid castings and forgings with higher natural frequencies have practically eliminated this type of vibration.

Aerodynamic vibration caused by gas flow is probably the chief source of noise and vibration in most control-valve installations. Most regulator stations handle pressure reductions at critical pressure drops or greater, and the resultant port velocities are extremely high. With port velocities of 70,000 ft/min it is estimated that the noise pressure level inside the valve body is about 170 decibels. The aerodynamic vibration spectrum is a mixture of frequencies in the octave bands 1200-2400 cps and 2400-4800 cps. These pressure pulsations, caused by the sound pressure waves, are transmitted through the pipe until coupled to piping walls with sympathetic frequencies. The walls then vibrate and retransmit the sound to the surrounding atmosphere.

Although the source of aerodynamic vibration is at the ports, the sound appears to originate in the piping. This is because the valve body, with its heavy wall sections and high mass reactance, attenuates or subdues the sound level at the valve, and the pressure pulsations actually are retransmitted by the piping. Occasionally, the piping wall vibration is of such magnitude that fatigue failure will occur. Consequently the use of heavier-wall pipe is recommended than is necessary to contain the pressure of the gas.

Another source of aerodynamic vibration is abrupt transitions in piping, such as entrance into headers, swedges, block valves, side-entrance tees, etc.

Reduction Techniques

Good piping *design* can cut down on the number of abrupt transitions, lessening the number of pos-

sible vibration points. On parallel runs, the use of oblique-angle entrance of one run into another should be considered.

Sound reduction also can be achieved by using *acoustic absorbing material* around the outside of the piping. Fisher's Research Laboratory has reduced sound-pressure pulsation by using acoustic material in the flow stream immediately downstream from the control valve. The acoustic material is held in by using strainer screen with 1/32" perforations. In the lab, an 8" pipe was used and the acoustic screen was extended for a 5' length downstream of the control valve. This reduces the pressure pulsations in the flow stream and minimizes the mechanical vibration of the piping.

Positioning

With all that is happening in the valve body, a rugged operator must be provided to keep the inner valve in the position dictated by the pilot. The most common actuator used for this job has been the diaphragm actuator positioned by a pneumatic controller.

Large valves must use large diaphragms. As large diaphragms are slow acting, relays usually are added to speed up the response. This can add to the control loop lag, causing cycling on small downstream systems. Such cycling normally can be stabilized by the use of a broad proportional band and a fast reset action, along with a slight bypass bleed around the relay. Using a spring range of 6-30 psig instead of 3-15 psig also helps on the power end.

More recently, the control-valve industry has brought out piston actuators which, by loading with 100-150 psig air or gas, can produce more power and thus move the inner valve faster. Springs can be added to these piston operators to provide fail-open or fail-closed action.

FIG. 2. PARALLEL-MOUNTED 4", 6" and 10" diaphragm control valves (Fisher Type 657AR) provide wide rangeability. One pressure controller (Fisher Type 416OR—center of instrument panel) operates 3 valves on split-range signal to positioner on each valve: 6-30 psig loading to each diaphragm is used for greater stability.

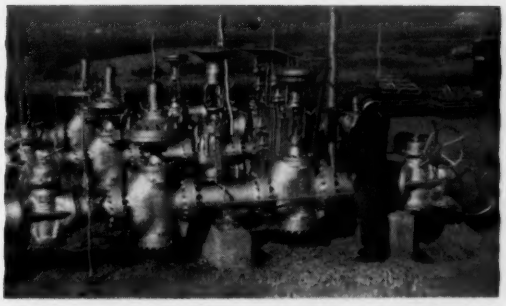


FIG. 3. THREE 10" pilot-operated pressure-balanced regulators (Fisher Type 885A) in parallel are shown at left. These offer fast response, close control with good stability, and no bleed gas to the atmosphere. Three 10" diaphragm control valves (Fisher Type 657AR) are being used at right as pilot-operated monitor regulators.

Multiple Runs

Where one valve can't handle the load over the wide range of inlet pressures, multiple runs can be used, with two or three valves in parallel. With graduated sizes, a system of wide rangeability results. Either (1) offset control or (2) split-range control can be used to control the valves. With either system, one valve commences to open as the preceding (smaller) valve reaches full travel.

With *offset control*, each valve would have its own pressure controller and its own pressure set point, offset from the next. The proportional band of each can overlap. With *split-range control*, one pressure controller is used and its output signal is split (Fig. 2). A positioner on each control valve responds only to its portion of the total signal. It is difficult to predict which system (offset or split-range) would give the greatest stability and the narrowest total proportional band. The choice of one system over another is largely a matter of preference.

An adaptation of split-range control has been used whereby motion transmitters on each valve open or close the control signal to the next valve at predetermined travels. For instance, at 85% lift the next larger valve is put in operation; at 15% lift that valve is taken out of operation. When the second or third valve is put in operation, the first and second valves throttle back. The valves that are in service operate in unison from the same signal from one controller. Although somewhat more complex than offset or split-range control, this system works well.

Pilot-operated pressure-balanced regulators, such as Fisher Type 885 (Fig. 3), offer another means of control; it is felt by many that this system will provide greater stability. Regulators of this type are more-or-less half pilot and half direct-acting. When you get a pressure change in the downstream system, you immediately get corrective action on the main inner valve because that pressure change is applied to the main-valve diaphragm. The pilot then comes along and finishes up the job. The inner valve isn't forced to wait for the signal response to proceed through a controller loop. The result is fast response with narrow proportional band and

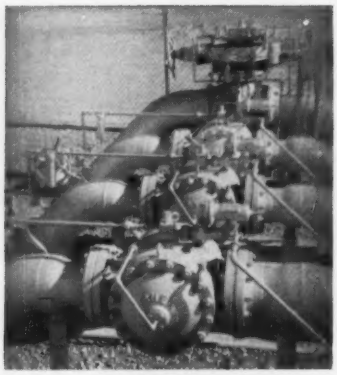


FIG. 4. THREE 8" expansible-element regulators (Fisher Type 282-6310H) in parallel. These offer fast response, good stability, no atmosphere bleed and a compact installation.

great stability. Another bonus is that there is no instrument bleed to the atmosphere.

The expansible-element regulator (Fig. 4) is also a pressure-balanced device, but the main valve (the expansible element itself) tends to open as the downstream pressure increases, which is just the opposite from the normal pressure-balanced device (and the opposite from what is desired). For this reason, a very stable pilot system must be used. However, this is a close-coupled system without the lag of an instrumented system, and stable control normally can be achieved, along with fast response.

Overpressure Protection

Overpressure protection usually must be tailored for the specific job. Shut-off valves, relief valves, monitor regulators and two-stage pressure reduction all have been used.

Monitoring and two-stage reduction seem to be the most popular solutions. Where space is limited and it is necessary to have the two sets of regulators short coupled, it might be best to protect the system by monitoring. This is because it might prove difficult to get stable control with a primary regulator sensing the pressure in the small volume between the two regulator stations.

If plenty of room is provided between the first and second stage (whereby stable primary control can be realized), a two-stage reduction provides an easier life for each regulator station.

If conditions are satisfactory for both systems, cost would probably be the deciding factor. With both systems, each regulator must be able to withstand the maximum upstream pressure; so cost would be equal from this point. However, there may be sizing differences which could greatly influence pricing, depending on what pressure drops are decided upon, and on the minimum inlet pressure to the station.

Start-up Impurities

One final point, and an important one—the purchase order for regulators normally specifies a given flow rate of natural gas. It doesn't mention the mixture of gas, welding slag, dust, sand, pipe scale and glass that often is encountered during the initial phases of pipeline operation. (The appearance of some of the inner valves and other internal parts makes one think that perhaps they are actually handling the four carloads of coal per hour used in the previous analogy.) This foreign material normally disappears after the first few weeks of operation but, by this time, a lot of damage can be done. Chrome-plated or completely Stellited surfaces can resist this attack better than stainless steel, but this isn't specified normally because of the extra cost. However, it is often less expensive in the long run to protect parts in this way.

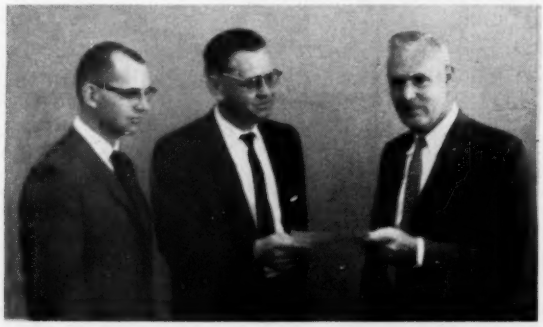
A better approach would be to filter out the foreign material ahead of the regulator station. This is often done on smaller stations, but it isn't done on the large high-pressure stations because of the high cost of the filters. It has been proposed to use temporary high-pressure filters at start-up, and then move them to some other location later for another start-up.

Another approach might be to hand-control the station with the block valves (while the regulators are wide open), or through the bypass (with the regulators closed) for a day or so, to reduce this initial wear from abrasive particles. Experience has shown that a short blow to the atmosphere (which is normally made) is not sufficient to clear the line, and the normal pigging operation doesn't pick up the foreign particles.

Acknowledgements

The assistance of Bill Vincent and C. F. King of Fisher Governor Company is much appreciated.

A loan fund to aid engineering students at California State Polytechnic College, Pomona, has been established by the Southern California Meter Association. Available for students at the Pomona campus of Cal Poly, the fund will have initial assets of $750, according to meter association president J. Marvin Lange. Awarded on a combined basis of merit and need, the fund is available either as (1) short term loans to assist students experiencing temporary financial need, or (2) as larger loans to enable students to finance their education. Photo shows **Mr. J. T. Cortelyou** (right), Chairman of the SCMA Loan Fund Committee, presenting check to **H. T. Skamser,** Dean of Engineering of California State Polytechnic. **J. Marvin Lange,** President of the SCMA, is at left.



The general-purpose EDA (Electronic Differential Analyzer) is usually a real-time analog computer. The EDA with repetitive operation presents successive solutions to a problem as parameters are varied. The iterative differential analyzer (IDA) uses iterative or numerical techniques to simulate the problem, permitting a broader range of mathematical tools to be used in attacking the problem. Iterative operation (IO) makes the IDA the most sophisticated and flexible analog computer ever developed. The EDA can be converted into an IDA simply by a change of control console.

Dr. Max Gilliland
Beckman/Berkeley Div.

The Iterative Differential Analyzer

THE DIFFERENTIAL ANALYZER (analog computer) directly integrates differential equations—this is the reason it was developed. Although various types of analog computers have evolved, most design effort has centered around the electronic differential analyzer (EDA) because electronic techniques are more sophisticated than mechanical techniques. Although the mechanical differential analyzer can integrate with respect to a dependent variable (whereas both the direct analog computer and the electronic differential analyzer permit integration with respect to only one independent variable corresponding to machine time), today it is an obsolete and seldom-used machine. Although a significant number of direct analog computers are in operation, their range of applicability is seriously restricted by their innate inability to simulate non-linear phenomena. The electronic differential analyzer, however, containing many non-linear machine elements, is suitable for the simulation of many such processes.

Analog Versus Digital Factors

The analog computer has two distinct advantages over the digital computer—(1) capacity for rapid problem solution, and (2) ability to integrate. Although the modern digital machine with large storage capability, high-speed arithmetic units and accompanying problem-oriented language (such as FORTRAN) is a powerfull tool for the evaluation of a specific mathematical model, generally the analog machine is still superior as a design or synthesis tool due to its computation speed and flexibility.

The digital computer cannot integrate. Consequently, *approximate integration* is carried out with a digital machine, using numerical techniques. However, when such techniques are used in the approximate integration of differential equations, serious problems arise.

Usually, the EDA is not suitable for the implementation of statistical studies because, due to the high accuracy normally required of its components, a restricted bandwidth has been imposed on the machine. Some analog manufacturers provide a machine with considerable bandwidth to satisfy this and similar requirements. However, a decrease in computation accuracy accompanies an increase in bandwidth. Consequently, the same machine generally can not serve both purposes.

In the past, analog computation has suffered from the requirement for redundant non-linear hardware and, more important, the inability to utilize iterative or numerical techniques. Recently, however, a new electronic differential analyzer with an iterative-operation mode* has evolved. In this machine the

*Although the term "repetitive operation" enjoys common usage in the field, the function of this new computer is more appropriately described as iterative operation.

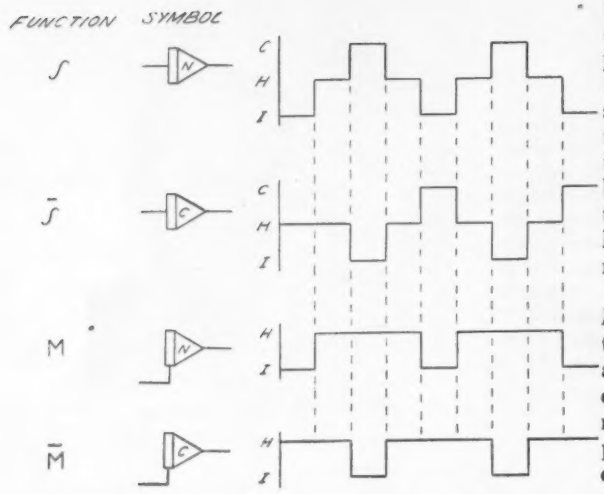
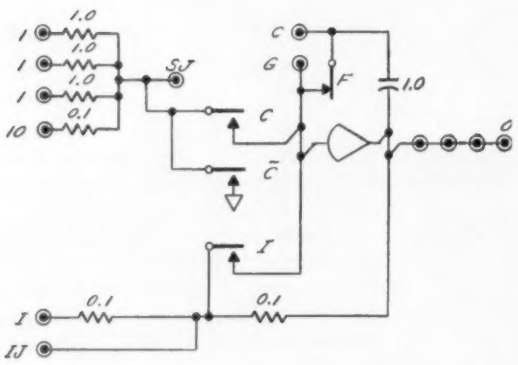


FIG. 1. Integrators and memories of an IDA, showing function, symbol and mode duty cycle. Top line $\int$ shows normal integrator; $\overline{\int}$ is complementary integrator; M is normal memory with IC input; $\overline{M}$ is complementary unit with IC input.



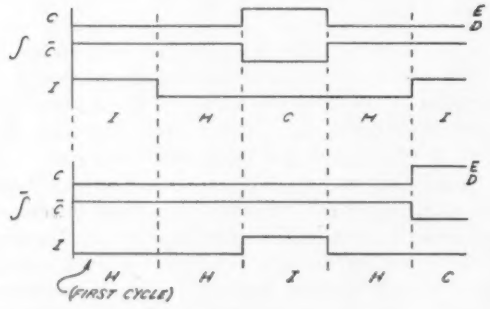


FIG. 2. INTEGRATOR with associated control relays (top). Graphs show duty cycle of relays during IO. Top graph shows normal logic; bottom graph shows complementary logic. E means energized; D means de-energized. Relays are normally de-energized.

inclusion of just one additional element, the inverse or complementary integrator, as well as more sophisticated control logic, has significantly increased the efficiency of hardware usage and expanded the simulation capability. Both incremental and continuous computation techniques can be used simultaneously. Further, both standard- and extended-bandwidth computation equipment can be used together in the same machine. These features now largely obviate the past computational limitations noted.

The new machine to be described is called the *IDA*—iterative differential analyzer. The IDA retains all the previous advantages of the EDA and also can function as an analog version of a digital computer. Essentially, a hybrid (analog-digital) mathematical model can be used to describe physical problems. This article explains the features of the typical IDA, and how its hardware provides this new capability.

The IDA Principle

The IDA differs from the EDA only with respect to control capability. Both the EDA and IDA contain integrators, summers, multipliers, dividers, function generators and decision-making modules as arithmetic elements.

Aside from more sophisticated control, only one new element is included in the IDA. This element is called a *complementary (C) integrator*. Basically, a complementary or C-integrator differs from the normal or N-integrator only with respect to the mode condition (Fig. 1).

The C-integrator generally finds application during repetitive (iterative) operation of the computer.

Fig. 1 shows the duty cycles of both the normal (N) and complementary (C) integrators during iterative operation. Note that whenever an N-integrator is in the compute mode, a C-integrator is in the initial-condition IC mode, and the converse (with the exception of the first cycle). Obviously the C-integrator cannot remain in the compute mode when the IDA is reset because initial conditions which are established for the N-integrators may cause the C-integrators to overload. Thus, initially, when the N-integrators are in the initial-condition mode the C-integrators are in the hold mode. The C-integrators can be reset in the pot-set mode. A standby switch is provided so that both the N- and C-integrators can be put in the initial-condition and hold modes, respectively, when the computer is operated manually. From the mode logic it is seen that during IO, data computed by the N-integrators can be used as initial conditions for the C-integrators, and vice versa.

Thus, a computation may be carried out which is described by two different sets of equations where the initial conditions for each depend on previously computed data from the other.

Programming Symbols and Mode Duty Cycles

Fig. 1 shows programming symbols used to denote the integrator functions, as well as their use

as memory units. If the only input to an N-integrator is a time varying voltage applied to the IC terminal, then the N-integrator will "learn" or track this voltage during the initial-condition mode, and hold or retain its value during the compute or hold modes. Thus, an N-integrator can be used as a memory.

Similar operation of the C-integrator provides a complementary memory. All other arithmetic modules in the IDA are independent of the mode condition during iterative operation.

We see from Fig. 1 that the N- and C-integrators can be used as normal and complementary memories with the proviso that no input be applied to the resistors connected to the summing junction. Thus, as shown, the N- and C-memories are essentially either in the initial-condition or the hold modes.

Implementation

Fig. 2 shows an operational amplifier being used as an integrator, together with its associated networks and control relays. The accompanying graph of relay duty cycles indicates the condition of these relays during iterative operation for an N- or C-integrator.

In contrast to previous practice, all these relays must have high operating speeds with adequate tracking. It is sometimes desirable to replace the I-relay with a solid-state switch so that iterative algebraic calculations can be performed at a high iteration rate.

The IJ terminal (which appears on the patchboard) can be connected to a spare resistive network to provide a capability for summing inputs to an integrator used as a memory. The F relay and the C terminal on the patchboard are used only in conjunction with a high-speed initial-condition module. The F relay is of the Form B type and is energized by inserting a pin into the appropriate hole in an auxiliary control pinboard.

Patchboard

Fig. 3 shows a simplified IDA integrator-summer patchboard configuration. The block of 15 terminals to the left makes available three resistive summing networks. Two of these are connected to amplifiers 02 and 03. Their common terminals are denoted by SJ. The remaining network is a spare, and its common terminal is denoted by J. If desired, the spare can be used in conjunction with the IJ terminal to sum inputs to the normal or complementary memories, as mentioned.

A pin can be inserted into one of the ∫, HG, or ∫ terminals to use the amplifier pair as N-integrators, high-gain amplifiers or C-integrators, respectively. If none of these three terminals is pinned, then the pair is used as summers. In an expanded IDA this control feature is implemented with an auxiliary control pinboard, thus significantly decreasing the number of patchboard holes required for control.

The application of 24 volts d-c to the S terminal

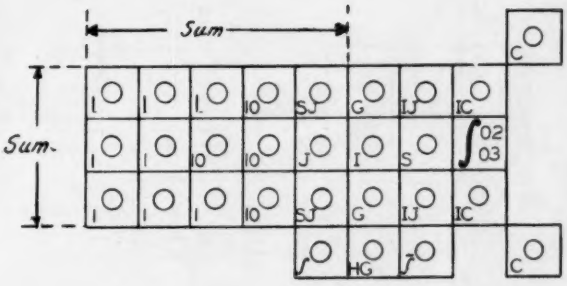


FIG. 3. INTEGRATOR-SUMMER patchboard configuration. Summing networks are at left (I, 10, SJ, J); C terminals are used only with the high-speed IC module. I and S are for control of the I relay.

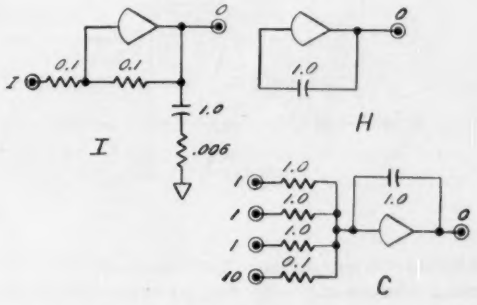


FIG. 4. SIMPLIFIED CIRCUITS for three basic intergator modes—I, H and C—to achieve high-speed IC.

energizes the I-relay. For normal operation this terminal is connected to the I terminal which comes from the initial-condition bus. This arrangement provides a convenient means for the arbitrary control of the I-relay. Again, this operation is usually implemented from the control pinboard instead of the patchboard. The C terminals are used only in conjunction with the high-speed initial-condition module.

High-Speed Initial Conditions

For iterative operation, a hold interval is provided between each pair of initial-condition and compute intervals (Fig. 1). This is done to allow sufficient time for information transfer between N- and C-integrators. The hold interval is chosen to be ten times the time constant of the integrator in the initial-condition mode.

If an integrator is used as a memory and is required to retain information throughout a considerable number of iterative-operation cycles, then integrator drift can become a problem. Sometimes this drift leads to inaccurate computation, depending on the numerical character of the mathematical model being implemented. Consequently it may be

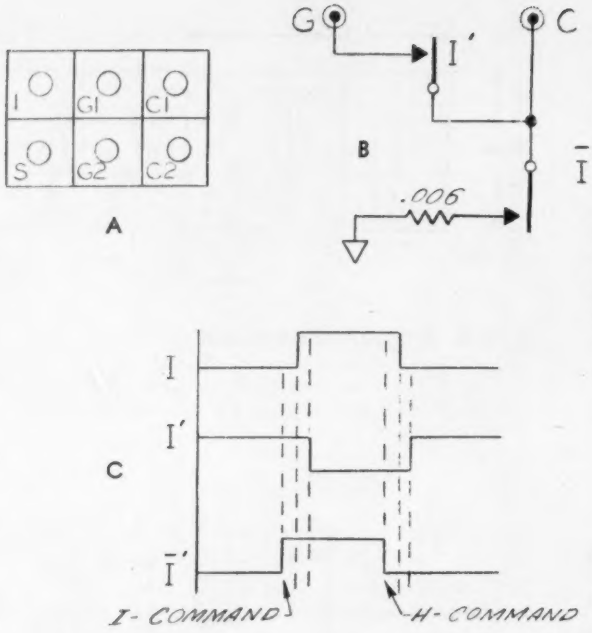


FIG. 5. HIGH-SPEED initial-condition-module patchboard layout (A). Terminals connect to the I′ and $\bar{I}'$ relays (B). Duty cycles of I, I′ and $\bar{I}'$ relays are shown at C.

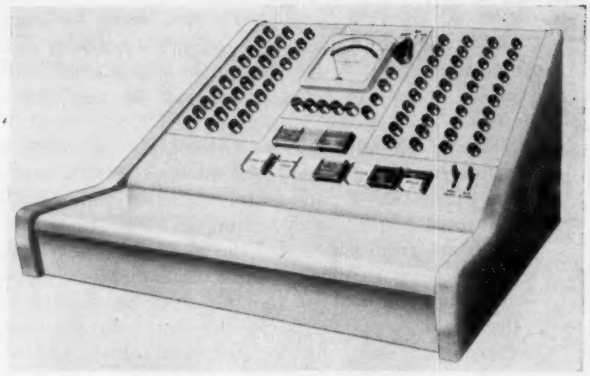


FIG. 6. TYPICAL control unit for an EDA.

desirable to use a larger time-constant, obtained by using a larger capacitor for the memory integrator. When this is done, the accurate transfer of information during the hold interval requires a different type of initial-condition circuit (Fig. 4).

Fig. 4 shows a simplified version of the high-speed IC circuit, together with the passive element configuration used in both the hold and compute modes. With the 1-μf integrating capacitor, a time interval of only 60 milliseconds is required to establish an initial-condition voltage to within 0.005%. This is accomplished by utilizing the entire current capability of the amplifier to charge the integrator capacitor through a 0.006-megohm resistor. A standard integrator can be converted to include this feature through the use of a high-speed initial-condition module, as follows:

The High-Speed IC Module

Fig. 5A shows the high-speed IC-module patchboard layout. In order to use this high-speed IC feature, the auxiliary control pinboard is utilized. Connections then are made from the module terminals to the corresponding terminals of the integrator pair (the I, S terminals will appear on the control pinboard in an expanded machine). Of course, the module may be wired internally if desired.

The internal details of this device are shown in Fig. 5B. Comparative duty cycles are shown for the I′ and $\bar{I}'$ relays* in 5C. Timing is accomplished by special circuitry in the module. Note that when the $\bar{I}'$ relay is energized and the I′ relay is de-energized, the fast-IC circuit shown in Fig. 4 is provided. When these relays are in the opposite state, the integrators are in the hold condition.

Fig. 6 shows a typical control unit for an EDA. Manual machine operation is implemented with the use of switches. A precompute switch provides a 5-second delay between compute command and execution. The computing elements can be placed under IO control by patchboard quadrants, or even smaller patchboard regions if desired. When the control pinboard option is provided, integrators may be placed under IO by pairs. Manual control of the C and $\bar{C}$ relays may be implemented with this pinboard. Thus, amplifier mode condition can be controlled by some dependent variable.

UIO and PIO

Two types of iterative operation control equipment are available—UIO and PIO. The UIO (utility iterative operation) and PIO (precision iterative operation) units are mutually exclusive options. Either is controlled from a panel near the main control unit.

With UIO both the compute and initial-condition intervals are continuously adjustable from ½ to 30 seconds. The hold interval is fixed at one second. An *iterative-operation* switch initiates the IO cycle and bypasses the *precompute* switch.

The PIO unit (Fig. 7) sets the hold interval equal to a time base which may be 0.01, 0.1 or 1.0 second. The initial-condition and compute intervals can be set independently to an integral multiple of the time base (ranging from 1 to 99) with their respective thumb switches. The *iterative-operation* switch initiates the IO cycle through a master cycle control clock. The *compute-stop* and *IC-stop* switches command the computer to remain in the respective hold modes, at the end of the next compute or IC intervals. This provides a convenient method of temporarily interrupting an iterative computation

*The bar over a symbol or letter is analogous to the NOT symbol used in symbolic-logic terminology.

FIG. 7. PIO unit.

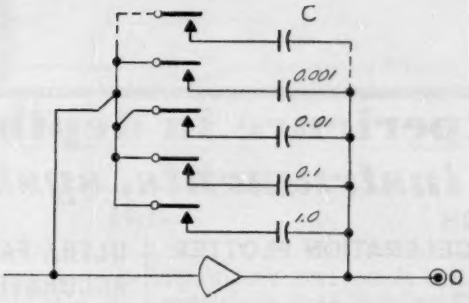


FIG. 8. OPERATIONAL AMPLIFIER with time-scale and iterative-operation capacitors. Additional capacitors can be added as desired.

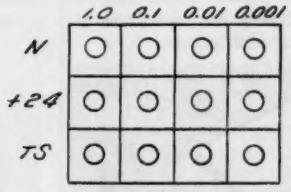


FIG. 9. PATCHBOARD use for manual selection of integrator capacitor.

to observe or record voltages in the computer. The *compute coincidence* switch accepts a hold command from an external source and bypasses the internal hold command. The *IC coincidence* switch performs the same function with respect to hold command at the end of the IC interval.

Nested IO

Some numerical techniques require the use of nested iterative operation. That is, some iterative calculation will depend on input data which in turn are calculated from some iterative process which is proceeding at a much higher IO rate. For example, this technique can be used for the evaluation of a multiple integral.

In order to implement nested IO, use is made of slave cycle-control clocks. Each slave is driven by its predecessor. Thus, the first slave is driven by the master clock, the second slave by the first, and so on. The slave clock has a time-base-multiplier thumb-switch which sets its time base equal to an integral multiple of the time base of its predecessor, ranging from 1 to 99. Slave IC and compute-interval thumb switches independently set these intervals to an integral multiple of the slave time-base ranging from 1 to 99. Amplifiers are controlled from slave clocks by groups. The master clock oscillator can either provide IO up to a 25-kc iteration rate, or be controlled externally.

If a high-frequency drive is used to control the master clock, it is necessary to use solid-state switching in the integrator initial-condition circuits. This type of control sometimes provides increased flexibility for nested iterative operation.

Automatic Time Scale

An automatic-time-scale option can be provided with both PIO and UIO to speed up the computation by a factor of ten. The IDA has a far more flexible integrator-capacitor selection system under time-scale control than did the EDA. EDA time-scale capacitor switching was accomplished with a form-C relay. Because of space limitations it was necessary to switch these capacitors by oven tray groups rather than individually. For the IDA integrator, however, capacitors can be switched by amplifier pairs with form-A reed relays.

Fig. 8 shows an operational amplifier with associated time-scale and iterative-operation capacitors. Note that additional special capacitors can be added as desired.

Integrator-capacitor selection is accomplished either automatically or with patchboard wiring. The patchboard arrangement for manual capacitor selection is shown in Fig. 9. Without patching, the integrator capacitor is selected automatically by the PIO control unit. As may be seen in Fig. 9, any of four different capacitors can be selected arbitrarily for certain amplifier groups, depending on the time-scale condition. When the auxiliary control pinboard option is provided, manual selection is made from the pinboard for integrator pairs.

Table 1 indicates the value of the integrator capacitors automatically selected as a function of both the time-scale condition and the position of the time-base switch for computers with time-scale option.

TABLE I—AUTOMATIC CAPACITOR SELECTION WITH TIME-SCALE OPTION

TIME BASE SWITCH SETTING	N CAPACITOR	TS CAPACITOR
EXT	0	0
1.0	1.0	0.1
0.1	0.1	0.01
0.01	0.01	0.001

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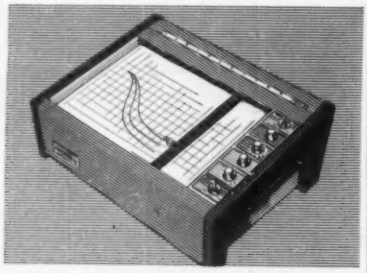

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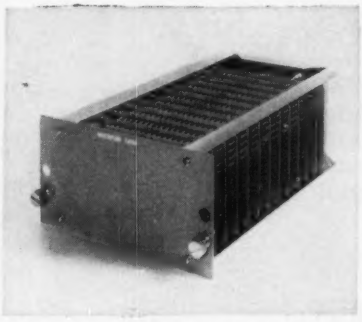

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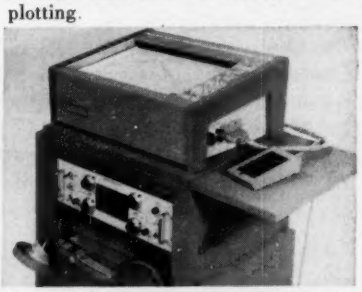

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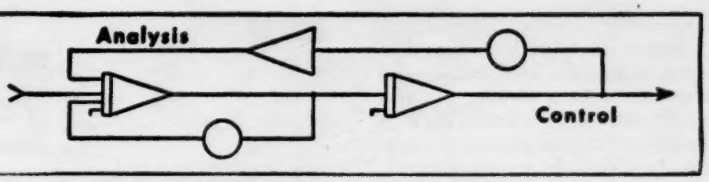

Newsletter

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Bits

This month the *Newsletter* gives you the word on the Western Simulation Council's meeting of last November on "Methods of Preflight and Postflight Simulation"—(1) **L. K. Yoskowitz,** "Pre- and Post-flight Simulation" and (2) **R. L. Wolpert,** "Automatic Computer Application to Northrop T-38 Inertia-Roll Coupling Analysis."

Also included for our readers' edification is an account of the Southeastern Simulation Council's meeting of last November, with abstracts of (1) **Fred Shaver,** "Development of a Practical High-Speed Digital Simulator," (2) **R. C. Nichols** and **J. B. Bailey,** "Analytical Description and Simulation of an Automatic Telemetry Tracking Antenna System," (3) **V. R. Brenes, R. W. Lanzkron,** and **W. Lee,** "Analog and Digital Methods for Analyzing and Compensating Missile Control Systems"

SCI Activities completes this month's issue. Sorry, but we have no **Thots!***

*Except to hope that you will want to join the Simulation Councils, if you haven't already done so. See the application blank at the end of this month's *Newsletter*.

Pieces

WESTERN S/C MEETING OF 10 NOV ON PREFLIGHT AND POSTFLIGHT SIMULATION

Lee Ohlinger, Chief of Computing and Datamation Center of the NORAIR Division of Northrop Aircraft (Hawthorne, Calif.) was host for the 10 November 1960 meeting of the Western Simulation Council. Subject of the meeting was "Methods of Preflight and Postflight Simulation".

We were not able to attend this meeting, but thanks to a request by **Hans Meissinger** we have received the following two abstracts.

Yoskowitz (Lockheed Aircraft, Sunnyvale) on Pre and Post-Flight Simulation

OBJECTIVES

Pre-Flight Simulation provides the means for checking the effects of launch environmental conditions. These conditions can be:

a. Winds at the launch site.
b. Missile angular rate and displacement command signals affecting launch recovery.
c. Effects of gain change in the control loop.
d. Effects of components response variation on missile controllability.
e. Change of an airborne programming device.

Post-Flight Simulation (1) provides the means for investigation and determination of undesired operation during a test flight. (2) Permits correction of a simulation by comparing flight-test data with parameters used in the simulation, e.g., thrust versus time.

SIMULATION METHODS

Simulation—"To assume the appearance of, without the reality; to feign."

All of the following methods may be used for pre- and post-flight simulation:

a. All analog.
b. Combination analog and flight hardware.
c. All digital.
d. Combination analog and digital computer. LMSD has not used this method.

Each of the simulation methods has a merit that is usually unique, the method used being a function of the specific problem type. For example,

the all-analog approach permits one to operate completely independent *of any hardware and its support* equipment, or to operate in non-real *time if necessary. In addition, it is* imperative that an all-analog simulation be available in order to investigate the effects of a hardware malfunction. In more than one case, it would be too time-consuming and expensive to deliberately modify a piece of flight hardware to simulate a hardware defect. General examples to illustrate the point are given:

1. **Loss of damping fluid in a gyro.**
2. **Obtaining an intermittent condition such as a short or open internal to the hardware.**
3. **Deriving a certain drift characteristic in a gyro.**
4. **Producing a desired deadband in the hardware.**

The combination analog and flight hardware method provides at least one benefit in that the hardware non-linearities are inherently included. Not that non-linearities could not be included in an all-analog, but to do so would require a definitive knowledge of the non-linearity. Malfunctions can be deliberately inserted in the hardware and the effect noted. A factor that may appear to be superficial is one that requires the simulation flight hardware to be like that flight-tested. It is easily possible for changes to be made to flight hardware that are not reflected in the simulation hardware.

The all-digital simulation serves a unique function in that repeatability and accuracy capability of the digital computer are utilized. That portion of the industry devoted to study trajectories and the effect of missile subsystem accuracies on these trajectories requires the digital computer. Information derived is used as a criterion for the analog type methods.

The hybrid analog-digital method —one which is not used in the Polaris Project—appears to provide the optimum in a simulation technique. The apparent beauty of this method is found in the division of simulation responsibility according to frequency content of the information operated on and the required accuracies. Quantities related to transformations, mass center motion, variation in air density lend themselves to solution by the digital computer; other quantities related to dynamics, autopilot and thrust vector control units are better done on the analog computer. Associated with the hybrid method is the requirement for communication between the computers. Basically, the link normally provides the bilateral capability of analog-to-digital and digital-to-analog conversion.

We are initiating an investigation to determine whether the Polaris Simulation Laboratory can realistically benefit by using a hybrid simulation.

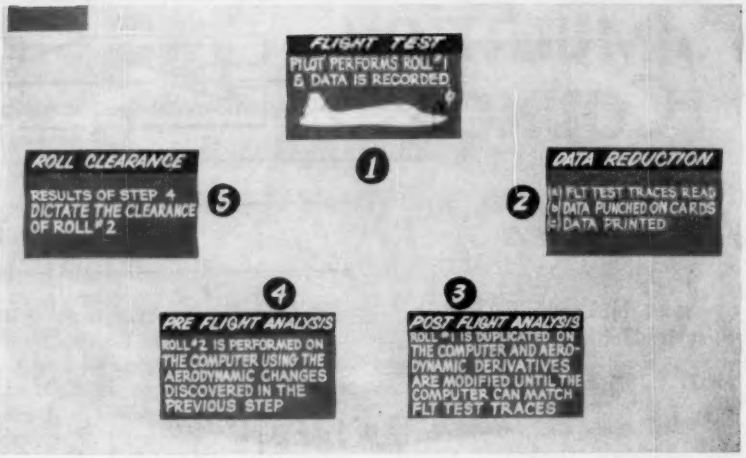

FIG. 1. Post-flight and pre-flight analyses.

Richard Wolpert (Norair) on "Automatic Computer Application to Northrop T-38 Inertia-Roll Coupling Analysis"

Two computers, one digital and one analog, have been mechanized in the NORAIR Computing Facility to investigate inertia-roll coupling phenomena of the Northrop T-38 Supersonic Trainer. This coupling phenomenon occurs during the performance of a rolling pullout maneuver and can, under certain conditions, cause large loads on the aircraft. The computer study is being performed in conjunction with a flight-test program to determine whether it is safe to perform rolling maneuvers in the T-38 throughout the flight envelope.

At each flight condition selected for investigation, a series of maneuvers is performed. The sequence of this series involves, first, doing the more moderate (or safer) rolling pullout maneuvers, and gradually progressing to those maneuvers which are less safe (large trim load factors at the time of roll initiation).

As indicated by Figure 1, the computer simulates each run that is performed by Flight Test (Post-flight Analysis). Any disagreements between the simulator run and the actual flight-test run must be explained before proceeding with the test program. Any changes (modifications of predicted aerodynamic data), which must be made in the simulator to make computer data match flight-test data then are used to predict the consequence of the discovered changes at the next scheduled maneuver (Preflight Analysis). Should the computer result of this prediction be satisfactory, the next scheduled maneuver is cleared for flight test.

Some advantages of employing a two-computer approach:

1. **The machines provide a check for one another.**
2. **A second approach is available, should one of the computers become unavailable.**
3. **Each computer has special application to certain types of analysis.**
4. **The availability of two computers speeds up the flight-test program.**

SOUTHEASTERN S/C MEETING OF 11 NOV.

The Southeastern Simulation Council met at ARO, Inc. (Arnold Engineering Development Center, Tullahoma, Tennessee) on 11 November 1961. We have no info on the first paper of the program, "Limit Cycle Phenomena Experienced in Missile Nose Cone Testing" by **Dick Lowndes** (ARO, Inc.), but thanks to **Jim Tootle,** Secretary of the Southeastern Council, we are able to give summaries of the other three presentations.

ROBERT C. NICHOLS has B. A., Mathematics, Carson-Newman College, Jefferson City, Tennessee, 1951; B.S.E.E., University of Tennessee, 1959. He is Electrical Engineer with Dynatronics, Inc., Orlando, Florida, and has been responsible for analysis of positioning servo system for 60' parabolic-dish automatic tracking antennas, including low pass filters, manual slew controls, and servo compensation networks. He has participated in the analogue computer simulation of the positioning servo system for automatic tracking antenna systems, and is member of IRE, Etta Kappa Nu.

Shaver on Digital Simulator

Second paper on the program was "Development of a Practical High-speed Digital Simulator" by **Fred Shaver** (Marshall Space Flight Center, Huntsville, Ala.). It described the general philosophy used in incorporating the digital-differential-analyzer modules (integrators, constant multipliers, variable multipliers, ΔY summers, and servos) developed by Packard-Bell Computer Corporation into a practical computer or simulator. An abstract follows:

These P-B modules operate with a clock frequency of 3.0 MC, 30-bit registers, and 100-Kc iteration rate. The goal was to make the operating and monitoring controls as nearly like those of an analog computer as possible. Decimal read-in and read-out as well as decimal display of all registers was a primary requirement. This was accomplished by the design of a Code Converter by Packard-Bell. Since each unit used in a problem must have an initial setting in its registers, paper tape input of initial conditions as well as manual input was required. An Electronic Associates type patchboard was used, with patchboard layout in module form. Six identical sections each provide terminations for 8 integrators, 4 constant multipliers, 1 variable multiplier, 2 servos, and 2 ΔY summers. Dual patching is required; both existence and sign must be patched. Contact troubles are more prevalent than in an analog computer because of the high-current, low-voltage circuitry.

The principal output is through digital-to-analog converters to conventional analog plotters or recorders. It is possible to punch out one variable at a time on paper tape which can be printed with an off-line Flexowriter.

Some special features specified and incorporated include:

(1) A slow iteration rate is provided for trouble shooting and for slowly varying coefficients during repetitive operation.

(2) Selective or total reset of units from an overflow signal or other command.

(3) Overflow alarm and optional automatic halt (hold in analog language).

(4) Read-in of initial conditions from tape on programmed command; this permits simple artitrary function generation.

After an initial rash of transistor failures, reliable operation has been achieved. Some test problems have been run successfully, and the capabilities of the machine are being expored.

Nichols and Bailey on Telemetry Tracking Antenna System

The next presentation was "Analytical Description and Simulation of an Automatic Telemetry Tracking Antenna System" by **R. C. Nichols** (Dynatronics, Inc., Orlando, Fla.) and **J. B. Bailey** (Martin Company, Orlando, Fla.). A summary follows:

In 1959 Dynatronics, Inc., under contract with the U. S. Navy, undertook the development of an automatic telemetry tracking antenna system. The military specifications called for the system to have a rather high velocity constant of 60 and an antenna gain of 30 db. The high antenna gain led to the use of a 60-foot parabolic reflector with the R-F feed assembly mounted at the focus. This assembly consists of R-F equipment and a conical scanning system designed by Dynatronics, Inc. The scanning system rotates at 600 rpm and conically nutates the antenna beam to obtain an error modulation.

The azimuth and elevation drive assemblies consist of two reliance Electric and Engineering Co. 20-hp motor-generator sets. These assemblies are conventional Ward-Leonard systems with the generator excitation supplied by transistorized magnetic amplifiers. This system is designated as the velocity servo and has both tachometric feedback and terminal voltage feedback for stabilization. The velocity servo is mechanically connected to the antenna through a gear box which is an integral part of the antenna tower.

The amplitude-modulated R-F signal is conected to the velocity servo by means of a demodulator and filter and a position amplifier which supplies the correct equalization for obtaining the desired Velocity Constant, K_v.

Design Considerations

Previous studies available to Dynatronics included only the antenna inertia, referred to motor speed, as a load for the servo system. The effects of compliance and viscous damping had not been considered further than a calculation of their orders of magnitude. The effects of wind-load torques on the over-all system performance were known only from linear mathematical analysis. The combined effects of these parameters and the range over which they could safely be allowed to vary made a fairly comprehensive study important.

For a system with this high a K_v, it was felt that non-linear components and their effects could not be neglected. Of particular concern were the effects of saturation and limiting. Also, a standard feature of this drive system is a current limiting device which is necessary to protect the motors at high wind loads.

Since these types of non-linearities do not lend themselves to analytical procedures, the decision was made to utilize an analog computer to design the position amplifier. A secondary, but important, benefit was the familiarity with the system that one would gain by taking such an approach.

Equations of Motion

It then was decided to accomplish the simulation by means of individual transfer functions rather than over-all equations. This would allow the computer to be used as a design tool for the position loop compensation and facilitate the variation of system parameters. The frequency response of the uncompensated system then would be obtained. Knowing this response, an equalizer would be designed and inserted into the position amplifier. The transient response under varying load conditions could then be ascertained and the fidelity

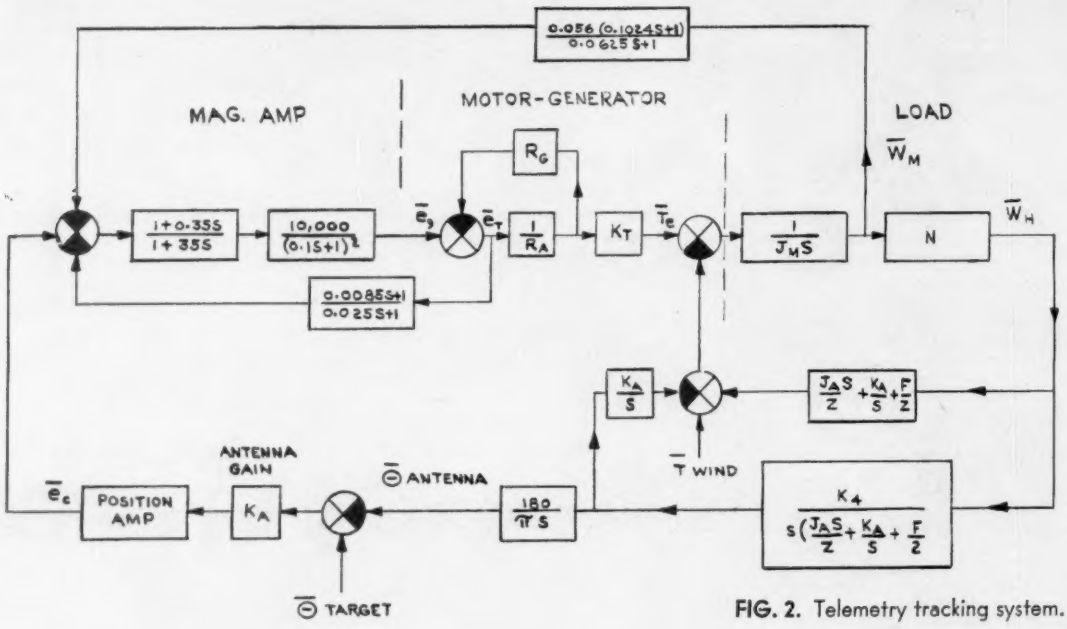

FIG. 2. Telemetry tracking system.

of the system determined. The block diagram of the system is shown in Figure 2.

Simulation

Figure 3 is a recording of the system response to a ramp input equivalent to a constant target velocity of 3°/second.

The tracking error for a target of this velocity and a system K_v of 60 should be

$$\theta_e = v/K_v$$
$$= (3°/\text{sec})/(60/\text{sec})$$
$$= 0.05° = 0.000872 \text{ rad.}$$

The response shows that this value is attained. In several of the runs the effect of the current limiter was noted. However, in no case did this lead to instability. For a 3°/sec ramp, the error settled to the above value in 7 seconds.

Conclusions

This project emphasized the use of frequency-response techniques in system engineering where an analog-computer served as the means of obtaining this response. After a suitable equalizer was designed, the computer allowed the transient response to be determined. The effects of changes in system parameters could then be determined.

The familiarity with the system gained from this study and a knowledge of the frequency response allowed a rapid final adjustment of the system to be made in actual field tests.

Brenes, Lanzkron and Lee on Missile Control

The final paper of the day was "Analog and Digital Methods for Analyzing and Compensating Missile Control Systems" by **V. R. Brenes, R. W. Lanzkron,** and **W. Lee** (all of the Martin Company, Orlando, Fla.). Some excerpts follow:

In the design of a ballistic missile system, it is necessary to provide a control system to stabilize and guide the missile along its prescribed trajectory. Stabilization is complicated by the fact that several of the structural bending mode frequencies usually lie within the band of required control frequencies. Therefore, the control system must be designed to provide stabilization for the "rigid-body" system and to attenuate the structural frequencies to such an extent that they do not cause an instability.

To study the control system, the equations of motion of the missile in linear operational form were obtained by first writing the equations of motion in the pitch plane, with flat earth and horizontal wind, and then linearizing by taking their total differentials. The resulting perturbation equations were then Laplace transformed to obtain the operational equations.

We won't go into the math here, but the result was a complete description of the linearized system.

Next it was necessary to consider whether to use analog or digital simulation. The nature of the equations

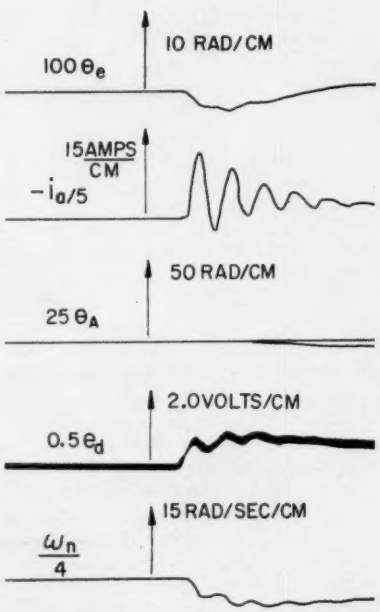

FIG. 3. Response to 3°/sec ramp.

indicated that analog mechanization was probably simpler than digital. Also, it is possible to include actual missile hardware in an analog simulation as a final check on the system.

At the Martin Company, however, we find that utilization of the analog is such that frequently we are not able to get rapid access to the analog computer. Rapid access is available on the IBM 709. In addition, the digital approach gives us the capabil-

Fourier integrals with parameter variations

$$A(u)\ \text{real} = 2\int_0^1 f(x)\left[\cos\left[(\psi(x)+ux)\right]+\cos\left[(\psi(x)-ux)\right]\right]dx$$

solved in 60 seconds...

$$A(u)\ \text{imaginary} = 2j\int_0^1 f(x)\left[\sin\left[(\psi(x)+ux)\right]+\sin\left[\psi(x)-ux\right]dx\right]$$

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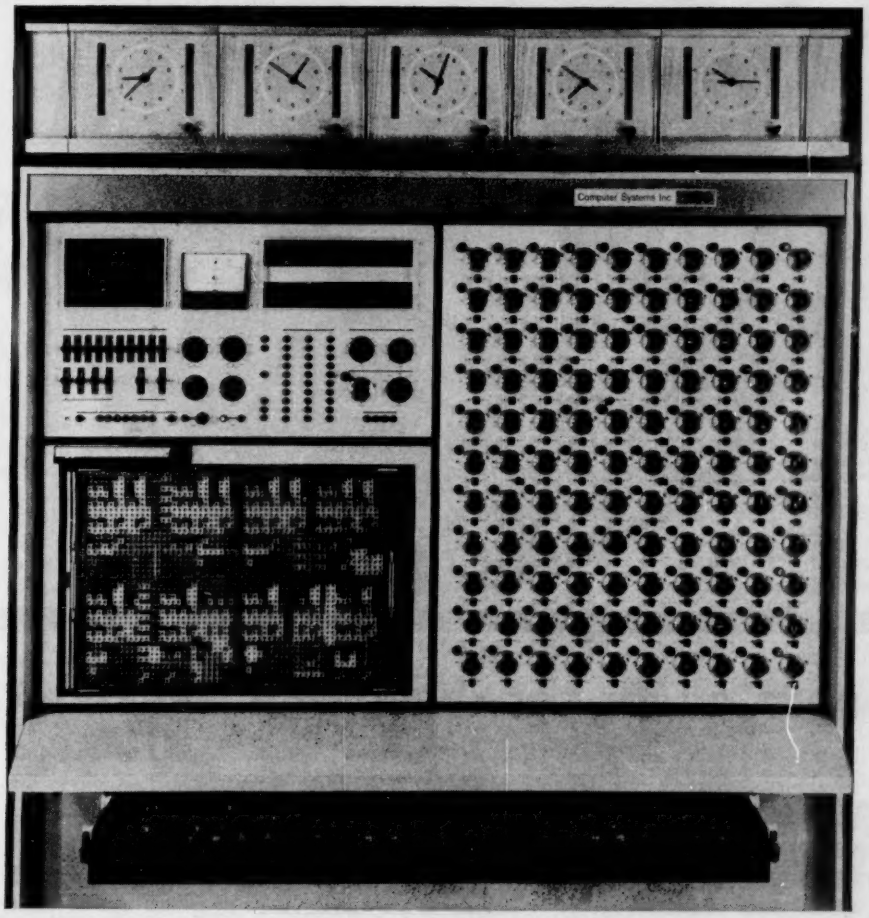

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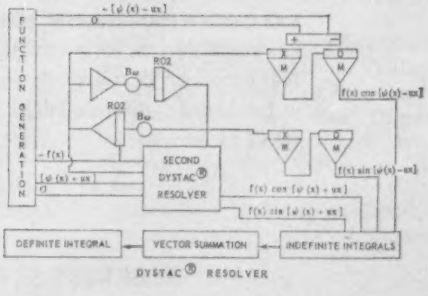
Send for our 11-page report, "Solutions to Bounded Fourier Integrals on the DYSTAC Computer."



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Lockheed Missiles and Space Division, Sunnyvale, California, leading research and development organization, beat its own schedule by three years and surpassed its own performance goals by wide margins to provide the Free World with the most important operational deterent to aggression: the Navy's POLARIS Fleet Ballistic Missile. • Lockheed has actually just crossed the threshold of space and defense programs. Future development of Polaris and other Lockheed space and missile programs will be more complex, intricate and demanding—will require research computation of a level and complexity never even envisioned. The problem-solving capacity of Beckman EASE Analog Computers meets this challenge.

LOCKHEED-EASE History EASE Analog Computers have participated in Lockheed success for over 5 years at the Lockheed-Georgia Division where the new Jet-Star executive jet transports and C-130 Hercules are manufactured and for over 2 years at Lockheed-California Division, famous for the Air Force F104 Interceptor and Navy P3VI Electra.

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Richmond, California

C-17

ity of obtaining both a time response and a frequency response of the system directly. For these reasons, the equations were mechanized in both analog and digital. This provides an excellent means of cross-checking.

After the problem was set up, a study of uncompensated Nyquist plots obtained from the digital simulation showed that an inner loop was unstable during the latter portion of the first stage flight and during most of the second stage causing the entire system to become unstable. This condition made necessary the inclusion of a compensating network in this loop to correct the instability.

During the first-stage flight time a type of phase compensation appeared to be suitable, while during the second-stage flight time an amplitude or attenuation compensation appeared more applicable. By proper choice of circuit configuration the required compensators were implemented with only one set of components and the additional aid of one relay. Inspection of the complete system's open-loop Nyquists, with and without compensation, showed that although the filter stabilized the inner loop, no appreciable degradation of system performance resulted. These digital results were then checked on the analog simulation.

The system was excited with step inputs and the resulting behavior was recorded. Missile performance and stability were determined from the response to the step inputs and the angle of attack and control angle signal were monitored to insure that these variables did not exceed the specifications of the system. Over-all system response was obtained and actual hardware then was substituted for the simulated filter, and results compared.

Because the digital results were normally in the form of frequency responses while the analog were in the form of time responses, a relationship between damping ratio and phase margin was derived in order to compare the two.

The comparison between results from both simulations was quite good, justifying a high degree of confidence in the design of the system.

THE SCI/GE SYMPOSIUM

We said we wouldn't report the Symposium on Combined Analog-Digital Computer Systems in detail because the Proceedings are available (from Simulation Councils Inc. at 8484 La Jolla Shores Drive, La Jolla, Calif.; five bucks a copy) but it occurs to us that we haven't told you what you'll get for your money. So herewith the Table of Contents:

1. Analog-Digital Computer Linkage System for Bendix G-15—R. E. Wright, EPSCO
2. Combined Analog-Digital Differential Analyzer (CADDA)—W. R. Urban, W. R. Hahn, Jr., H. K. Skramstad, National Bureau of Standards
3. Some Aspects of Computer Linkage System Design—W. J. Peet II, Electronic Associates Inc.
4. The Combined Analog-Digital Computer System—M. Paskman, J. Heid, GE-M&SVD
5. A General-purpose Analog-Digital System—M. L. Stein, University of Minnesota
6. A Combined Analog-Digital Computer for Simulation of Chemical Processes—S. Shapiro, L. Lapides, IBM Research Laboratories
7. Evaluation of an Intercept Trajectory Problem Solved on a Combined Analog-Digital System—H. Gilman, GE-M&SVD
8. Hybrid Computer Setup for Missile Flight Analysis and Control—G. Hintze, H. McJunkin, Flight Simulation Lab. WSMR
9. Air Traffic Control System Simulation—A. Jackson, H. Ottoson, Thompson-Ramo-Wooldridge Corp.
10. Timing Consideration in a Combined Simulation System—E. Hartsfied, STL
11. Diagnostic Programs for a Combined Analog-Digital System—K. Feucht, GE-MSVD
12. Programming for a Closed-loop, Manned Machine Combined System—D. C. Friedman, National Bureau of Standards
13. Scaling and Information Transfer in Combined Analog-Digital Computer Systems—G. Birkel, Jr., Radiation, Inc.
14. Combined Simulation at STL—L. W. Neustadt, G. A. Bekey, STL
15. Hybrid Digital Differential Analyzer General-Purpose Computer System—O. A. Reichardt, Packard-Bell
16. High-speed High-Accuracy Linear Segment Hybrid Function Generator—F. Schmid, Link Division—General Precision, Inc.
17. Future Applications of Combined Systems in Planning and Control—D. F. Blumberg, J. Diebold Assoc.
18. Recent Experiments in Missile Flight Dynamics Simulation with the Convair "Addaverter" System—A. N. Wilson, Convair-Astronautics

SCI Activities

WESTERN Simulation Council Meeting of 1/12/61

Lawrence Alexander, who spoke on "Simulation Methods in Man-Machine Simulation Research," and **Milton Holmen,** who spoke on "Use of Simulation in Training," have been kind enough to send me abstracts of their presentations, so—with the others previously announced—we will be in good shape to report that meeting, which we will do shortly.

MIDWESTERN Simulation Council Meeting of 1/16/61

Robert Hanett has sent me more, much more, material on their meeting that I believe you would care to read, so my work is cut out for me! However, with the intriguing title "Novel Solutions to Nasty Problems," it should be worth the effort.

Program Announcements Received

SOUTHEASTERN Simulation Council 27 January 1961, Georgia Institute of Technology, Atlanta

"An Analog Data-Processing Device for On-Line Use in Medical Research," Georgia Tech Analog Computer Laboratory.

"Instrumentation of the Moving Average," Georgia Tech Analog Computer Laboratory.

"A Fourier Integral Computer for the Calculation of Antenna Radiation Patterns," Scientific Atlanta, Inc.

"A Low-Drift Recycling Integrator for Physiological use," A. F. Spear, Physicist, Medical College of Alabama.

Discussion of the recent Combined Analog-Digital Computer Systems Symposium.

Tour of RadioIsotopes Laboratory, demonstration of nuclear reactor simulator and 1-MEV Van de Graaff generator.

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Here's why:

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- It is the only method for accomplishing these checks — BEFORE the problem is run and without the introduction of new errors.
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CIRCLE 92 ON READER-SERVICE CARD

Tour of Scientific Atlanta plant, demonstration of Fourier Integral Computer.

Tour of Georgia Tech Analog Computer Laboratory.

Dinner meeting: speaker, **Dr. L. D. Wyly** of Georgia Tech School of Physics, on "Why an Interest in Nuclear Power?"

MIDWESTERN Simulation Council, Rackham School of Graduate Studies 13 March 1961, of the University of Michigan, Ann Arbor

Subject: "Analog Equipment—New Types and Future Needs"

"The Use of Silicon Junction Diodes in Analog Computation" by **R. M. Howe** (University of Michigan)

"Continuous Data Analysis with Analog Computers Using Statistical Regression Techniques" by **Arthur I. Rubin** (Princeton Computation Center of Electronic Associates, Inc.)

"An Improved Variable Transport Delay Circuit" by **W. J. King** and **V. C. Rideout** (University of Wisconsin, Madison).

"The Application of Poisson Cells in the Design of Electron Injection Systems" by **J. E. Rowe** and **R. J. Martin** (University of Michigan)

"Frequency Analysis of Seismic Waves with an Analog Computer" by **R. E. Crabtree** and **V. L. Larrowe,** (University of Michigan)

Tour of the University's Phoenix Project, or

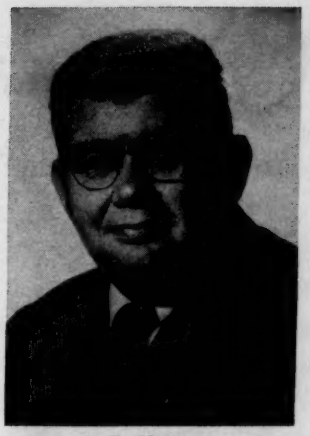
Tour of the Institute of Science and Technology of the University of Michigan's Analog Computer Laboratory near the Willow Run Airport.

SOUTHEASTERN Simulation Council; 14 April 1961; University of Alabama

* * *

JOHN E. SHERMAN, Manager of Analog Computing at the Lockheed Missiles and Space Division in Sunnyvale, California, has been elected Chairman of the Board of Directors of Simulation Councils, Inc. for 1961.

Simulation Councils, Inc. is a non-profit California corporation interested in computers and similar devices which make use of mathematical and physical analogies. The purpose of Simulation Councils, Inc. is to advance the design, development, construction and application of computers and simulators, not only in science and engineering, but in other fields of human endeavor as well. Simula-



J. E. Sherman

tion Councils, Inc. is organized on the basis of regional councils whose main purpose is to promote the free interchange of ideas and information concerning the art and science of simulation. There are seven regional councils composed of more than 1200 members. The regional councils are: Western Simulation Council, Mid-Western Simulation Council, Central States Simulation Council, Rocky Mountain Simulation Council, Eastern Simulation Council, Southeastern Simulation Council and the Digital Differential Analyzer Council.

Membership is $3 per year, and includes a subscription to the *Simulation Council Newsletter* in *Instruments & Control Systems*. Application can be made to the Secretary, Suzette McLeod, 8484 La Jolla Shores Drive, La Jolla, Calif. An interest in computers is the basic requirement.

Application for membership in SIMULATION COUNCILS INC., 8484 LaJolla Shores Drive, LaJolla, Calif.

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.....

Business address and Title .....

References (Persons familiar with your professional work):

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2. .....

3. .....

Age ..... **Years of professional experience** .....

Education and degrees .....

Major work interests .....

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I&CS NEW INSTRUMENTS

CALIBRATION STANDARD

New Model 1900 DC Semi-Automatic Instrument Calibration Standard has 21 voltage ranges from 0-150 μv to 0-1500 v, and 20 current ranges from 0-15 μa to 0-30 amp for standardizing and calibrating d-c voltmeters and ammeters to ±.05% accuracy.—*Radio Frequency Laboratories, Inc., Powerville Rd., Boonton (Twp.), N. J.*

CIRCLE 211 ON READER-SERVICE CARD

FREQUENCY STANDARD

New atomic Frequency Standard uses optically pumped rubidium cell as basic frequency reference, has stability of 2 parts in 10 billion, maintains accuracy of less than 1 sec of error in 750 years. Device has application in terrestrial and space navigation, is portable for calibrating instruments.—*STL Products, Div. Space Technology Laboratories, Inc., Box 95001, Los Angeles 45, Calif.*

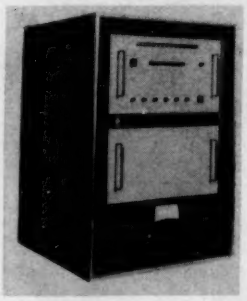
CIRCLE 212 ON READER-SERVICE CARD

LOGIC MODULES

Thirteen new modules for data processing applications include Dual Flip Flop, And-Or Inverter (4 inputs to 4 inverters), Gate Circuit (8 Capacitor-Diode Gates), Analog Switch, etc.—*Digitrols, Inc., 8223 Old Philadelphia Rd., Baltimore 6, Md.*

CIRCLE 213 ON READER-SERVICE CARD

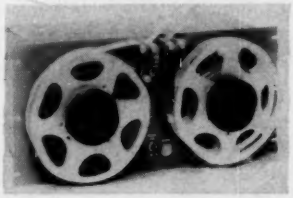
TIME QUANTIZER



New LFQ-10 solid-state automatic high-speed Quantizer system measures or quantizes time intervals to resolution of 10 millimicrosec. One version for use in 3-dimensional missile tracking systems permits high altitude measurements to resolution of ±2½'.—*Computer Equipment Corp., 11612 Olympic Blvd., Los Angeles 64, Calif.*

CIRCLE 214 ON READER-SERVICE CARD

TAPE SPOOLER



New TS-400 Automatic Tape Spooler, first accessory equipment for use with 400-series unidirectional and bidirectional tape readers, is bidirectional winding 15-ips spooler, may be used with any tape reader. Unit uses standard reels up to 8" dia for handling 1000' paper or mylar tape. Data Sheet TS-400.—*Electronic Engr. Co. of Calif., 1601 E. Chestnut Ave., Santa Ana, Calif.*

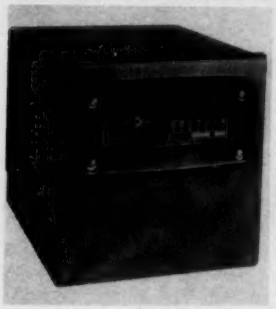
CIRCLE 215 ON READER-SERVICE CARD

ADDING MACHINES

New solenoid-activated Premier Digit-Matics print up to 4 lines/sec, feature 2-color printing and rear-cable connection, come in both parallel entry (full keyboard) and serial entry (10-key) machines. Optimum pulse duration is 35 msec.—*Victor Adding Machine Co., 3900 N. Rockwell St., Chicago 18, Ill.*

CIRCLE 216 ON READER-SERVICE CARD

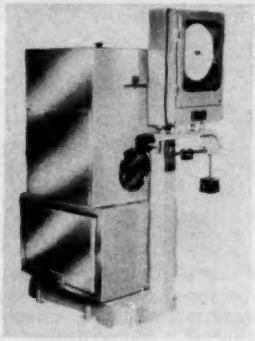
PNEUMATIC TOTALIZER



New panel-mounted Pneumatic Totalizer multiplies flow rate by time to give total flow, receives linear or square root pneumatic signal between 3 and 15 psi and converts air pressure into direct readout of total flow. —*B-I-F Industries, Inc., 345 Harris Ave., Providence 1, R. I.*

CIRCLE 217 ON READER-SERVICE CARD

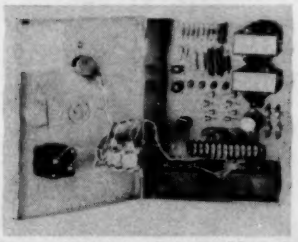
RECORDING DRY FEEDER



New scale-mounted Series A-690 Feeder with Loss-of-weight Recorder controls dry-chemical flow at rates between 0.0045 and 2.8 cu ft/hr; records amounts on 24-hr or 7-day charts. Solution tank gives thorough mixing; water jets help dissolve all chemical.—*Wallace & Tiernan Inc., 25 Main St., Belleville 9, N. J.*

CIRCLE 218 ON READER-SERVICE CARD

SERVO POSITIONER



New solid-state Power Max integral horsepower position servomechanism components and systems feature positioning accuracy better than 0.5%. D-C input signals include: positioning potentiometer, selector switch and fixed resistor network, static switching circuits, electromagnetic flowmeter, tape programmer.—*Electromation Co., 4254 Glencoe Ave., Venice, Calif.*

CIRCLE 219 ON READER-SERVICE CARD

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1959 CHART OF THE ATOMS

Chart and 48-page KEY booklet both completely revised

by Dr. William F. Meggers, National Bureau of Standards

- Improved readability
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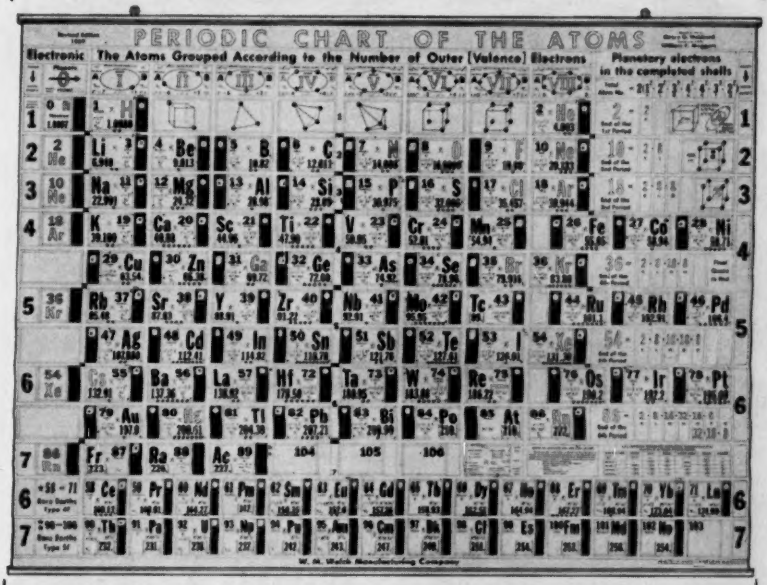
- Lists latest atomic weights compiled by International Union for Pure & Applied Chemistry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CIRCLE 220 ON READER-SERVICE CARD

MINI CERAMIC SWITCHES

New line of Switches that withstands temperatures to 175°C uses specially developed high-temperature alloys and incorporates new assembly techniques that assure their high temperature operation. Switches provide up to 22 terminals per section; maximum switching combinations per section range from 1 pole with 2 to 12 positions, to 6 poles with 2 positions.—*Centralab, Electronics Div. of Globe-Union, Inc., 900 East Keefe Ave., Milwaukee 1, Wis.*

CIRCLE 221 ON READER-SERVICE CARD

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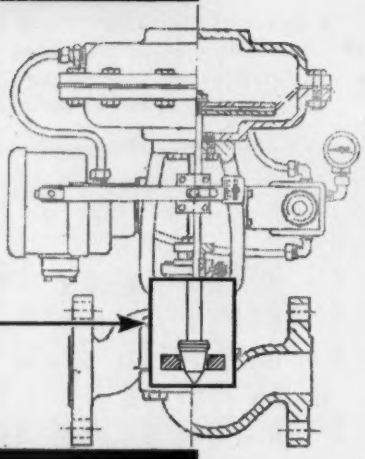
The Inside Story on Unlimited Cv range is here



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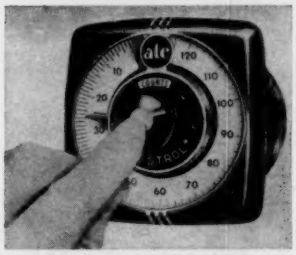
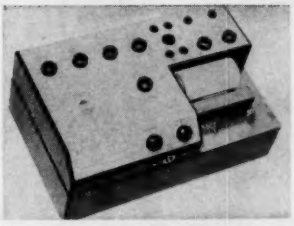
IMPULSE COUNTER



New Series 311 Atcotrol "push-button" Impulse Counter counts at rate up to 500 cpm; features built-in Start Button integral with count-setting knob, 1 or 2 SPDT Snap-action 10-amp-load switches, impulse-type motor with long life, non-reset upon power failure, counting on four standard count ranges.—*Automatic Timing & Controls, Inc., King of Prussia, Pa.*

CIRCLE 222 ON READER-SERVICE CARD

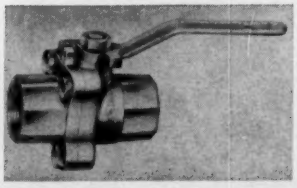
RMS RECORDING VOLTMETER



New Level Recorder Model 2305 high-speed graphic Recording Voltmeter measures true RMS, average, or peak level of a-c signals from 10 c/s to 200 kc/s or signals dc to 10 c/s through internal chopper. Recorder operates as null balancing, electromechanical servo with 6-linear or logarithmic recording ranges of from 10 to 75 db. Brochure BK 2305.—*B & K Instruments, Inc.*, 3044 *W.* 106 *St., Cleveland* 11, *Ohio.*

CIRCLE 223 ON READER-SERVICE CARD

BALL VALVE



New F-125 Forged Naval Bronze Ball Valve for use with air, water, or fluids compatible with bronze features "Auto-Mating" valve seats that provide positive sealing in either flow direction throughout valve life. Spring, retainer ring and O-ring seal behind valve seat insure constant compression, self-adjustment and tight seal even on low pressure and vacuum lines.—*Ball Valves, Inc.*, 41 *Jackson St., Worcester, Mass.*

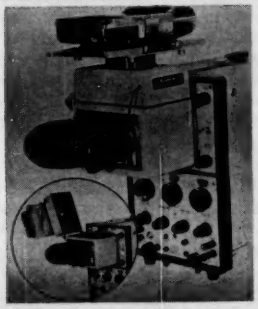
CIRCLE 224 ON READER-SERVICE CARD

D-C MICROVOLTMETER

New electronic (all-transistor) D-C Microvoltmeter Model 1362 (and Model 1362R) operates by rechargeable nickel-cadmium) storage battery, has full-scale range of voltage from 1.0 mv to 1000 v; accuracy, ±1.0% of full scale. Voltage Ranges: ±1000 to ±1 v, ±300 to ±1 mv. Input Impedance: 100 megohms or greater on all ranges.—*Dynamics Instrumentation Co., 583 Monterey Pass Rd., Monterey Park, Calif.*

CIRCLE 225 ON READER-SERVICE CARD

OSCILLOSCOPE CAMERAS



New Types 3000, 3001, 3002, and 3003 Oscilloscope Cameras for use on all existing oscilloscopes feature binocular viewing, Polaroid film backs, choice of three lenses, and accessories for versatility. Building-block design permits altering basic camera characteristics.—*Analab Instrument Corp., 30 Canfield Rd., Cedar Grove, N. J.*

CIRCLE 226 ON READER-SERVICE CARD

MAGNETIC TAPE TRANSLATOR

New Magnetic Tape Translation Devices provide computers with lower-cost on-line input conversion of foreign tape formats and signals. Unit translates tapes by using reading computer's ability to edit information, converting pulse shapes, format, and timing into form equal to that supplied by computer's tape readers. Bulletin AE305.-68.—*Auerbach Electronics Corp., 1634 Arch St., Phila. 3, Pa.*

CIRCLE 227 ON READER-SERVICE CARD

REFERENCE VOLTAGE SOURCE

New Model 350 Reference Voltage Source for use with null-seeking galvanometer-type indicating controllers has 3-digit dial, 1° adjustment of setpoint. Null balance circuitry eliminates effect of lead-wire length on calibration. Over-all measurement sensitivity is 0.25°F.—*Wheelco Instruments Div., Barber-Colman Co., 1515 Rock St., Rockford, Ill.*

CIRCLE 228 ON READER-SERVICE CARD

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MODEL R
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CIRCLE 97 ON READER-SERVICE CARD

TAPERED ZIPPERTUBING

New tapered Zippertubing offers a tight-fitting cable jacket for cables of decreasing diameters due to branch-outs. Supplied to customers' specifications.—*Zippertubing Co., 752 S. San Pedro St., Los Angeles 14, Calif.*

CIRCLE 229 ON READER-SERVICE CARD

SOLDERLESS TERMINAL

New Terminal, the T-30 Solderless Springclip, holds up to six leads without soldering and may be used over and over. Fits any round 0.093" hole. Contact resistance between leads and the terminal is less than 0.003 ohms.—*Vector Electronic Co., 1100 Flower St., Glendale, Calif.*

CIRCLE 230 ON READER-SERVICE CARD

CHASSIS SLIDES

New Chassis Slides are available in three sizes of six types. All accommodate 17" chassis.—*Bud Radio, Inc., 2118 E. 55th St., Cleveland 3, Ohio.*

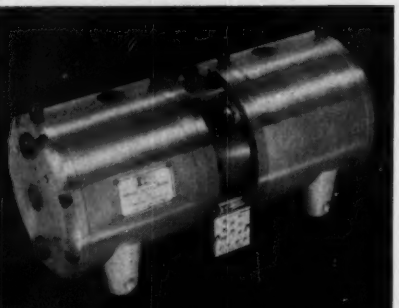
CIRCLE 231 ON READER-SERVICE CARD

HEAT SINKS

New line of 6030 Heat Sinks features all-aluminum construction and anodized finish. Special hardcoat-anodize is available which withstands over 1000 v rms. Bulletin gives details.—*Vemaline Products Co., Franklin Lakes, N. J.*

CIRCLE 232 ON READER-SERVICE CARD

dynamic new concept of vibration testing produces



NEW PRIME ACCELEROMETER CALIBRATOR

Here's further proof of the advantages of ITT's dramatic new approach in air-suspended, lateral motion accelerometer calibrators: the ST-200 vibration exciter. Developed at the request of a major Government facility for their *prime* standard, the ST-200 will provide *double the accuracy* of other known standards.

The unique concepts of air-suspension and lateral motion that provide the performance features of the new ST-200 are also an integral part of other ITT vibration exciters for secondary and routine accelerometer calibration. These same techniques are easily adapted to other special vibration and shock testing requirements.

For complete information, applications data and performance curves, contact your ITT representative or write for Data File ICS-1469-1.

Other ITT vibration exciters for accelerometer calibration may be integrated into your present system design or can be ordered as part of complete, self-contained ITT testing systems.

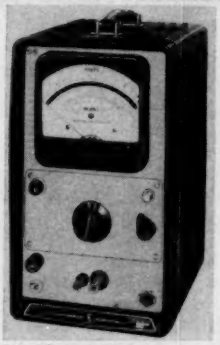
ST-110 for secondary standards

ST-115 for routine calibration

ITT **Industrial Products Division**
International Telephone and Telegraph Corporation
15191 Bledsoe Street • San Fernando, Calif. • EMpire 7-6161
power conversion • instruments • closed circuit TV • avionics • mobile radio/telephone

CIRCLE 98 ON READER-SERVICE CARD

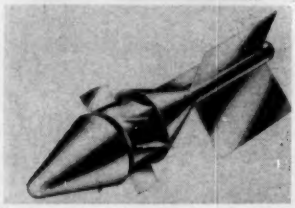
ELECTRONIC VOLTMETER



New Model 317 Voltmeter measures 300 mv to 300 v at frequencies from 10 cps to 11 Mc, is useful as null detector from 5 cps to 30 Mc. As calibrated amplifier it provides stable gain up to 60 db with frequency response ±1db from 6 cps to 11 Mc.—*Ballantine Laboratories, Inc., Boonton, N. J.*

CIRCLE 233 ON READER-SERVICE CARD

FLOW TRANSDUCER



New turbine-type Flow Transducer design permits constant hydrodynamic balance of rotor without use of thrust bearings; increases accuracy, reliability, and life.—*Francisco Engr. Co., 23987 Ventura Blvd., Calabasas, Calif.*

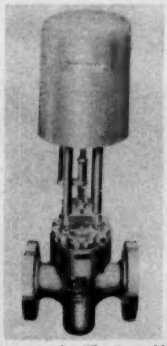
CIRCLE 234 ON READER-SERVICE CARD

TAPE RECORDER/REPRODUCER

New VR-2600 Wide Band Magnetic Tape Recorder/Reproducer features frequency response to 500 kc on direct record, 40 kc on FM, and 1000 bits per inch parallel recording with PCM techniques; six electrically selectable operating speeds from 1⅞ to 120 ips in two ranges; all solid-state plug-in modular electronics; and all metal front surface side-band record and reproduce heads.—*Consolidated Electrodynamics Corp., Subs. Bell & Howell, 360 Sierra Madre Villa, Pasadena, Calif.*

CIRCLE 235 ON READER-SERVICE CARD

SERVOACTUATOR



New Pneumatic Hydraulic Servoactuator for pneumatic control systems requiring high-power level positioning employs 3-15 psi (or other standard) pneumatic command signals to control 500-4500 psi hydraulic power sources. Features speed of response and positioning resolution; linear or characterized stroke.—*Boonshaft and Fuchs Inc., Hatboro Industrial Park, Hatboro, Pa.*

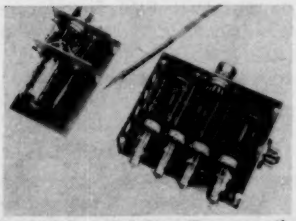
CIRCLE 236 ON READER-SERVICE CARD

ACCELEROMETER

New Model 609 8-oz Accelerometer features damping assembly fully temp-compensated and relatively insensitive to viscosity changes, friction-free multiplying potentiometer pick-off device that incorporates flexure principle, eliminates all bearings. Independent dynamic error band ±0.6 to ±0.8%; resolution to 0.25%; natural frequency (undamped) from 14 cps at 0-1 G to 120 cps at 0-70 G.—*Bourns, Inc., 6135 Magnolia Ave., Riverside, Calif.*

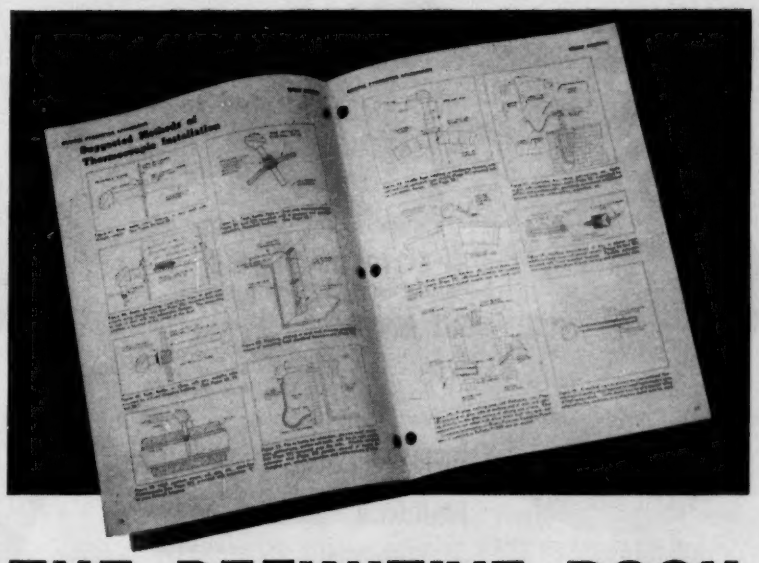
CIRCLE 237 ON READER-SERVICE CARD

COUNTER



New high-reliability Counter (left) uses 75% fewer parts than previous model, has increased reliability through use of single counting tube instead of usual ring-counter employing four tubes.—*Franklin Electronics Inc., Bridgeport, Pa.*

CIRCLE 238 ON READER-SERVICE CARD



THE DEFINITIVE BOOK

on thermocouples and pyrometer accessories

It's still Bristol's big 56-page "Buyers' Guide and Users' Manual"—yours for the asking.

One of the most useful publications ever directed specifically to the industrial pyrometer user, this buyers' guide catalogs Bristol's comprehensive line of thermocouples, protection tubes, thermocouple wire and radiation unit accessories. But, in addition to this, it's a compendium of technical data for the pyrometer user—essential to newcomers to the field, valuable reference data to the old hand. Here's just a partial listing of topics discussed:

- Thermocouple types
- Factors affecting thermocouple life
- Thermocouple reproducibility
- Calibrated thermocouples
- Thermocouple insulation
- Thermocouple protecting tubes
- Thermocouple extension wires and cold-end compensation
- Selecting the right thermocouple and protecting tube
- Responsiveness of thermocouples

... plus more than 165 illustrations, plus 8 pages of thermocouple calibration tables. It's a manual you can't afford to be without. Write for your copy of Bristol's "Thermocouple and Pyrometer Accessories Buyers' Guide and Users' Manual," Bulletin No. P1238, today. The Bristol Company, 154 Bristol Road, Waterbury 20, Conn. 0.32

BRISTOL ...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

CIRCLE 99 ON READER-SERVICE CARD

WRITE-ON LABELS

New Perma-Shield Labels combine a color-bordered write-on label with a tough, glass-clear Mylar shield. The shield is applied over the written-on label, slightly overlapping the entire perimeter so all edges are completely, permanently protected. Both label and shield are pressure-sensitive. Furnished in twelve different sizes.—*W. H. Brady Co., 727 West Glendale Ave., Milwaukee 9, Wis.*

CIRCLE 239 ON READER-SERVICE CARD

SOLAR DEMONSTRATION KIT

New compact, inexpensive Demonstration Kit, Cat. No. 81090, that shows solar energy at work consists of 12 silicon solar cells, a small motor and a three-blade propeller. Manufactured by the Semi-conductor Div. of Hoffman Electronics Corp., and distributed by *Central Scientific Co., 1700 W. Irving Park Rd., Chicago, Ill.*

CIRCLE 240 ON READER-SERVICE CARD

SPECIFICATIONS
Fig. 378 and Fig. 379

SIZE RANGE:	½" - 3"
TYPE:	Spring-opposed Pneumatic Cylinder with Positioner
SUPPLY PRESSURE:	36 psi - Fig. 378 18 psi - Fig. 379
POSITIONER RANGE:	3 - 15 psi standard (others on application)
POSITIONER ACTION:	Air to Open (Close on Air Failure) or Air to Close (Open on Air Failure)
MANUAL ACTUATION:	Nut on valve stem
ACCESSORIES:	Air Filter and Pressure Reducing Valve

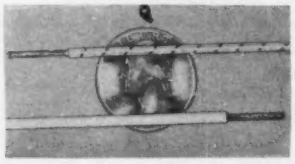
Specifications ARE ONLY HALF THE STORY

THERMAL TIMING RELAY

New Type DM Thermal Timing Element provides instantly resettable time delays in the range from ¾ to 5 seconds. Delay interval comprises a short heating period followed by a longer cooling period, leaving the thermal element cool and ready for another cycle. Setting tolerances are normally ±10%.—*G. V. Controls Inc., Okner Parkway, Livingston, N. J.*

CIRCLE 467 ON READER-SERVICE CARD

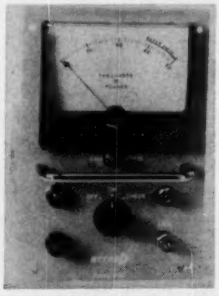
SATELLITE WIRES



Two new radiation-resistant, miniature instrument wires for satellite use are offered in sizes 24 through 16 AWG. Style 1 (above) is for use in sealed capsules; Style 2 (below) withstands environmental dielectric test of 1500-v after 90 days immersion in tap water, indicating prelaunching stability.—*Boston Insulated Wire & Cable Co., 25 Bay St., Boston 25, Mass.*

CIRCLE 468 ON READER-SERVICE CARD

METER INDICATOR



New Model 470 Meter-Indicator indicates output of strain gage transducers; is packaged with transistor amplifier, power supply, and wide-scale meter. Scale graduates to indicate any measured variable directly; proportional secondary d-c output voltage, 0-1v, available for control or recording purposes. Bulletin 103-A.—*Bytrex Corp., 50 Hunt St., Newton 58, Mass.*

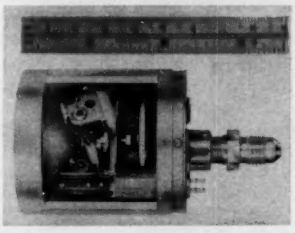
CIRCLE 241 ON READER-SERVICE CARD

FAULTFINDER

New portable Brunt Faultfinder quickly traces overhead pipe, line and cable signals, and locates accidental grounds. Detection is done on power systems (both ac and dc) up to 600 v while the system is energized.—*Park Mfg. Corp., 44 Austin St., Newark, N. J.*

CIRCLE 242 ON READER-SERVICE CARD

PRESSURE TRANSDUCER



New TP-200 5-oz potentiometer-type Transducer withstands 75 G's; measures absolute, gage or differential pressures of corrosive or non-corrosive gases or liquids in 0-5 and 0-500 psi full-scale range, also altitude, airspeed, pressure ratio and Mach number. Static error band of ±2.5% in 0-5 to 0-10 psi range.—*Fairchild Controls Corp., 225 Park Ave., Hicksville, N. Y.*

CIRCLE 243 ON READER-SERVICE CARD

DUAL POWER SUPPLY

New compound-regulated Dual Power Supply, Model R-500, consists of two separate regulated supplies on one chassis, with a common reference, which provide ±300 vdc, each rated at 500 ma. Specification sheet gives further information.—*George A. Philbrick Researches, Inc., 285 Columbus Ave., Boston 16, Mass.*

CIRCLE 244 ON READER-SERVICE CARD

Performance IS THE REST

You can see much of the merit of a DeZurik Control Valve in its specifications. But you can't really appreciate all of its advantages until you have one in service. Then its performance takes over.

For instance, you don't have minimum leakage tolerances with DeZurik Control Valves; they close tight—dead tight! Their straight-thru flow permits higher capacity, size for size, than zig-zag or weir type valves; a 3" DeZurik Valve has a flow coefficient of 330.

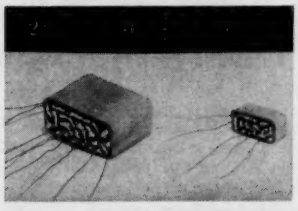
Want more? There's no stem leakage to contend with. Rangeability is extremely high with excellent control at both ends of the flow curve. Nothing extra to pay for manual operation provision, it's standard . . . in fact, total price is much lower than you'd expect to pay for such trouble-free, precision control.

You can get more details from the DeZurik representative in your area, or write us for Bulletin 150.

DeZURIK CORPORATION
SARTELL, MINNESOTA

CIRCLE 101 ON READER-SERVICE CARD

AMPLIFIER MODULE



New Type APC 3-transistor, RC-coupled, printed-circuit amplifier module (0.858 x 0.413 x 0.728) is 4 times larger, has over 10 times output (9 mw into 300-ohm inductive load) of N-E1 module (at right). Two types—output impedance of 1 K and 0.3 K—draw 2.3-7.5 ma when operating on 1.3 v or 3 v.—*Fidelity Electronics, Ltd,* 4120 *W. Lawrence Ave., Chicago* 30, *Ill.*

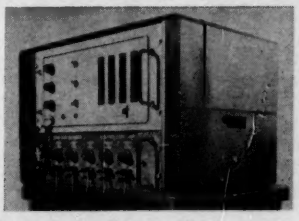
CIRCLE 245 ON READER-SERVICE CARD

ANNUNCIATOR NAMEPLATE

New Magna-Plac Nameplate features 70% more engraving area by elimination of a metal frame around the white translucent acrylic cover. Overall dimensions are 3¾" x 3⅜", of which 3⅜" x 3⅛" is useable engraving area. Standard nameplates are 2¼" x 2¾" overall.—*Scam Instrument Co.,* 1811 *W. Irving Park Rd., Chicago* 13, *Ill.*

CIRCLE 246 ON READER-SERVICE CARD

STRAIN GAGE RECORDER



New 5-channel solid-state Strain Gage Recorder uses Transponders to eliminate low-level amplifiers and solid-state multiplexer for estimated $8,000 saving over conventional systems. Recorder is accurate within 0.2% of full scale in measuring output of strain gage bridge circuit.—*Electro-Logic Corp.,* 515 *Boccaccio Ave., Venice, Calif.*

CIRCLE 247 ON READER-SERVICE CARD

IR-SENSITIVE TV CAMERA

New infrared-sensitive TV Camera can "see" object (steel plate when it reaches 850°F or burglar prowling around IR-illuminated bank). Also, ultraviolet-sensitive vidicon camera enables closed circuit TV camera to increase usefulness of UV microscope by picking up pictures from it.—*Fairbanks, Morse & Co., Electronics Div.,* 505 *Oakwood Ave., West Hartford* 1, *Conn.*

CIRCLE 248 ON READER-SERVICE CARD

RADIATION FUEL GAGE

New Nuclear Gage measures amount of fuel in airplanes and missiles, is not affected by changes in al-

titude or cosmic radiation. Gamma rays given off by radioactive source (shown in cylinder tip) are picked up by detector. Intensity of gamma rays depends on amount of fuel.—*Atomics International, Div. North American Aviation, Inc., Box* 309, *Canoga Park, Calif.*

CIRCLE 472 ON READER-SERVICE CARD

FOR MORE INFORMATION ON ANY PRODUCT, USE INQUIRY CARD BOUND INTO THIS ISSUE

Morehouse PROVING RINGS

FOR ACCURATE LOAD CALIBRATIONS TODAY, TOMORROW ETC. ETC. ETC. ETC.

Not just accuracy, but *sustained* accuracy makes the Morehouse Proving Ring the accepted standard of force measurement. Once calibrated by the National Bureau of Standards, it is unsurpassed in dependable repeatability. The basic simplicity of its design assures retention of initial accuracy — 1/10 of 1% — over long periods of time. For full details, write for "The ABCs of ACCURACY."

NEW UNIVERSAL CALIBRATING MACHINE

Designed to best utilize the precision of the proving ring in the calibration of both compression and tension-type load cells. The new model features an adjustable yoke and a two-speed precision jack for easier operation. For details, write for Bulletin 193.

MOREHOUSE
MACHINE COMPANY
1742 Sixth Ave. • York, Pa.

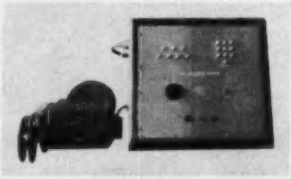
CIRCLE 141 ON READER-SERVICE CARD

COMPUTER FORMAT RECORDER

New Model S-2010 Computer Format Recorder accepts data simultaneously from telemetry, instrumentation and digital data processing sources; processes acquired data directly onto computer format magnetic tape. Unit can be completely slaved to associated input system, with necessary gaps, parity bits and markers generated automatically.—*Systems Div., Epsco, Inc.,* 275 *Massachusetts Ave., Cambridge* 39, *Mass.*

CIRCLE 249 ON READER-SERVICE CARD

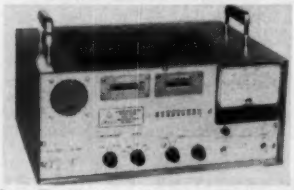
SHAFT ENCODER



New low-cost Shaft Encoder Translation System consisting of translation unit and paper tape punch accepts output of standard shaft encoders and coverts data into 12-bit 8-4-2-1 binary-coded decimal form, then prepares converted data on punched paper tape, complete with parity checks. Front panel push-buttons for manual preparation of non-test or arbitrary data.—*Electronic Development Corp.,* 423 *W. Broadway, Boston* 27, *Mass.*

CIRCLE 250 ON READER-SERVICE CARD

COUNT-RATE METER



New Radiation Counter Laboratory Model 20306 Scaler Count-Rate Meter accepts signal pulses from organic or halogen-filled Geiger counter tubes, is easily operated. "Timer" records minutes to 999.99; count-rate unit provides ranges of 500, 5000, 50,000 cpm. Counting rate circuit and meter combined have accuracy better than ±3% of full scale on each range.—*Durant Mfg.,* 1914 *N. Buffum St., Milwaukee* 1, *Wis.*

CIRCLE 251 ON READER-SERVICE CARD

Order Your Personal Copy–NOW

Process Control **$2.00**

by A. J. Young. A "must" for all who have to do with the automatic control of of industrial processes, this book combines for the first time the practical "how" and the theoretical "why". Paperbound, 134 pages, 1957 (second printing).

Process Control Analysis **$2.00**

by M. H. LaJoy and E. A. Baillif. An essential first step in analysis of closed-loop controlled processes via frequency response of the system. Clothbound, 72 pages, 1956.

100 Electronic Circuits—Vol. 1 **$2.00**

by M. H. Aronson and C. F. Kezer . . . covers amplifiers, oscillators, pulse circuits, phase shifters, etc. Complete with all circuit component values and response specifications. Paper, 180 pages, 1957.

100 Electronic Circuits—Vol. 2 **$2.00**

Second in the series by Aronson and Kezer. Vol. 2 also gives complete values and specifications for 100 "new" circuits not covered in Vol. 1. Complementing each other perfectly, the two volumes become a powerful circuitry design tool. Vol. 2, Paperbound, 1960.

The Automatic Factory **$1.50**

by June, et al . . . a fresh viewpoint on what "manless factories" can be . . . free from the generalities, and misconceptions so prevalent on this subject. Cloth, 88 pages, 1955.

Nuclear Reactors for Industry and Universities **$2.00**

edited by E. H. Wakefield. The several distinguished authors and editor Wakefield cover types, availability (1954), operation, protection, control, experiments, legal aspects, and present a detailed cost sutdy. Cloth, 92 pages, illustrated, 1954.

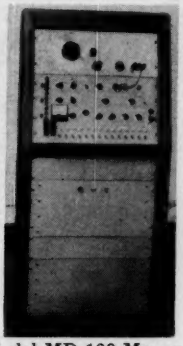
Scientific and Industrial Glass Blowing **$5.00**

. . . and Laboratory Techniques by W. E. Barr and Victor J. Anhorn. New revised edition covers construction in detail. Explains operating principles of all pieces.

Includes review of history, and most recent developments. Original edition acclaimed "best of its kind—not only on glass blowing but hundreds of techniques." Paper, 408 pages, 300 illustrations . . . new edition 1959.

Instruments Publishing Co., Inc.
845 Ridge Ave.
Pittsburgh 12, Penna.

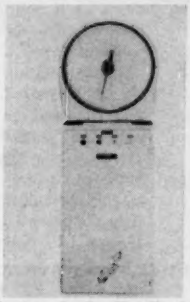
DRUM CHECK-OUT SYSTEM



New Model MD-100 Magnetic Drum Check-Out System, first test equipment available for recording timing tracks and providing general check-out of magnetic drum system," offers clock recording, clock smoothing, origin and word track recording, and test pattern recording. Clock track is recorded circumferentially around drum with preselected number of bits, up to 16883; closure better than 50 millimicrosec.—*FMA, Inc., 142 Nevada St., El Segundo, Calif.*

CIRCLE 252 ON READER-SERVICE CARD

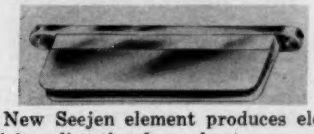
ELECTRONIC LADLE SCALE



New electronic Ladle Scale for accurate (to ±¼%) net weight weighing of hot metal (to 250,000 lb live load) uses 3 tension-mounted electric load cells, eliminates maintenance problems. Load is indicated on 20" circular scale located in scale house; two remote printers record weight on punched tape.—*Gilmore Industries, Inc., 13015 Woodland Ave., Cleveland 20, Ohio.*

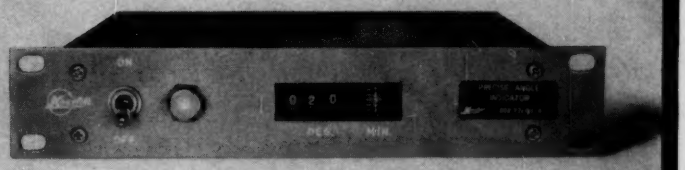
CIRCLE 253 ON READER-SERVICE CARD

THERMOELECTRIC POWER



New Seejen element produces electricity directly from heat, connects in series-parallel or any combination into any configuration to create compact generators (Seejenators), provides infinite variety of voltages, resistances, and currents. Air- or liquid-cooled Seejenators provide heat sink as well as power in avionic applications.—*Harco Laboratories, Inc., 77 Olive, New Haven, Conn.*

CIRCLE 254 ON READER-SERVICE CARD



HIGH-ACCURACY PRECISE ANGLE INDICATOR

NEW KEARFOTT UNIT ACCURATE TO ±6 MINUTES

The new CO 2721011 Precise Angle Indicator features an accuracy of ±6 minutes. Latest addition to the Kearfott line of standard test equipment, the unit is designed to meet a wide range of applications. Typical Applications • Indication of gyro angle of pitch, roll, or yaw and relaying of signal to any preselected impedance or voltage level. • Indication of shaft position of remote synchro or resolver, and transmission of this information to any impedance or voltage level. • Display of difference between two shafts when driven by transmitter and differential synchros.

In addition to high accuracy the instrument combines a number of other prominent advantages: it requires only a single power source; it has good sensitivity; it is designed for modular application; and it offers direct automatic read-out. The unit is of extremely compact construction and is built for maximal ease of maintenance.

The low-cost CO 2721011 Precise Angle Indicator is available with a single sensor, auxiliary dual-input sensor, or an auxiliary retransmitter. For additional information on this new test instrument, write for the brochure which describes its operation and capabilities in detail.

SPECIFICATIONS

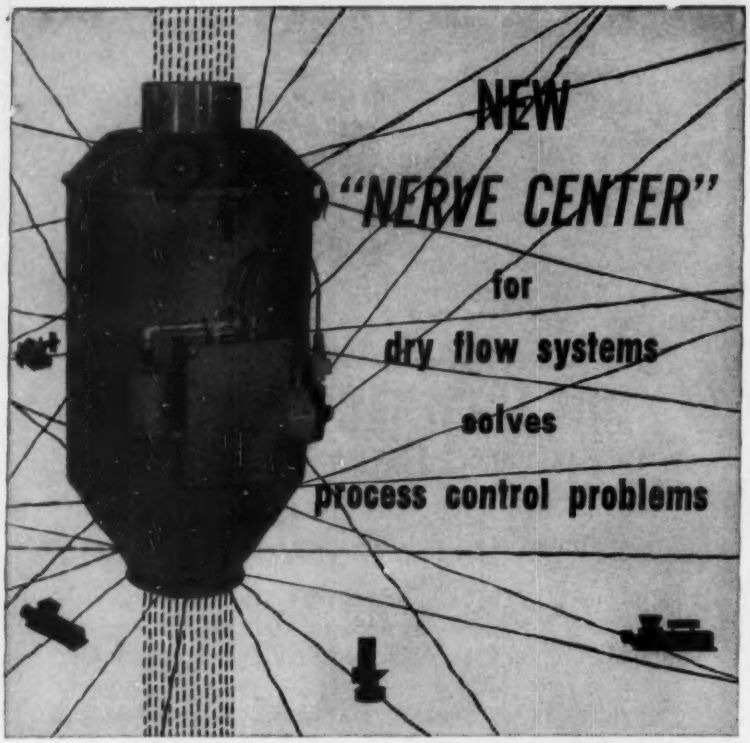
Repeatability	±1.2 min	**Slewing Speed**	7 sec/180°
Readability	0.5 min	**Power (single source)**	115 v, 1φ, 400 cps
Input Power	30 va	**Size**	1¾ x 9½ x 9⅛ in.
Sensitivity	1.0 min	**Weight**	4 lbs.

Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

CIRCLE 104 ON READER-SERVICE CARD



The new W&T Massometer® senses flow in closed systems. It measures dry, free-flowing materials and translates the results into a 3-15 psi signal. The unit can be used to indicate or record. It also controls proportional blending . . . helps solve problems in all kinds of control situations.

And the Massometer does all this without breaks in your closed system. Air-tight construction means a flow-sensing unit that seals dust in . . . seals contamination out. It is compact and easily installed, fits neatly into the line. Stainless steel for parts exposed to the flow stream and dust-tight motor casing assure years of maintenance-free service.

The Massometer is calibrated with any maximum output between 40 and 200 lbs. per minute. Maximum volumetric capacity is 6 cubic feet per minute. Repeatability within ±0.2% of full scale assures stable performance.

By generating a signal proportional to flow, the W&T Massometer brings a new look to ratio control. Its versatility means more accurate batch processing, or helps create continuous processing in new or existing systems.

For information, write Dept. M-50.48

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

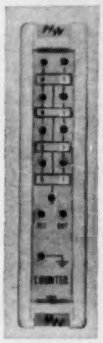
CIRCLE 105 ON READER-SERVICE CARD

HUMIDITY INDICATOR

New portable Indicator provides simple and rapid means of determining % relative humidity from 20 to 100% (RH). Dry bulb and wet bulb temps read on two dial-type thermometers having accuracy of ±1%, are interpolated on self-mounted slide rule.—*George Instrument Co., 559 E. Jefferson Ave., Detroit 26, Mich.*

CIRCLE 255 ON READER-SERVICE CARD

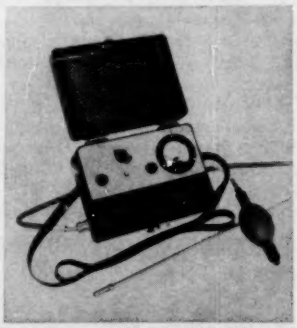
4-STAGE BINARY COUNTERS



New Model 1231 4-stage binary counter Data Bloc modules cascade by front-panel banana-jack connections to produce counts of length. Logical "one" and "zero" outputs available at every stage. Also available in Data Pac printed-circuit board module style, interconnect through taper pin connectors.—*Harvey-Wells Electronics, Inc., 14 Huron Dr., Natick, Mass.*

CIRCLE 256 ON READER-SERVICE CARD

LEAK DETECTOR



New Therma Bridge Helium Leak Detector Model HDL incorporates hand-pumped rubber aspirator bulb for use where no 115-v a-c power is available; Model HDLP has small 115-v a-c operated vibrating-reed pump to draw gas through detector for scanning. Two-range feature permits high sensitivity pick-up of small leaks while minimizing overdrive on large leaks.—*Industrial Instruments, Inc., 89 Commerce Rd., Cedar Grove, Essex County, N. J.*

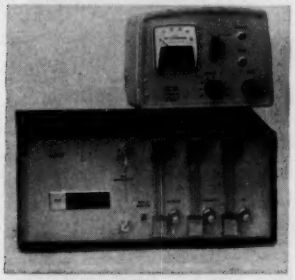
CIRCLE 257 ON READER-SERVICE CARD

METERING VALVES

New Mod-U-Flow spool-type Valve adjusts by straight-line actuator linked to stem, which has total linear motion of 2". Spool cylinder has spiral groove of increasing depth which meters flow of non-corrosive liquids depending on what point along graduated groove is exposed at intake.—*Hill Machine Co.*, 1301 *Eddy Ave., Rockford, Ill.*

CIRCLE 258 ON READER-SERVICE CARD

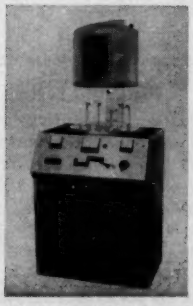
GAS MONITOR



New GAMAD Gas Monitor and Adjuster monitors and controls flow of air, nitrogen and hydrogen required by FIAD Flame Ionization Analyzer and Detector. Permits total hydrocarbon analysis of batch samples from 20-40 cc volume, continuous analysis of gas stream from pressurized source, and gas phase chromatography with use of external chromatographic column.—*Carad Corp.*, 3381 *Junipero Serra, Palo Alto, Calif.*

CIRCLE 259 ON READER-SERVICE CARD

LAB VACUUM SYSTEM



New Model 94700 Laboratory Vacuum System features implosion-proof, 18"-dia aluminum bell jar that can be evacuated within 5 min to 1 micron of mercury (ultimate vacuum of 2×10^{-3} mm). Single-lever operated three-way valve prevents errors due to conventional valve operation in wrong sequence.—*Central Scientific, Div., Cenco Instruments Corp.*, 1700 *Irving Park Rd., Chicago* 13, *Ill.*

CIRCLE 260 ON READER-SERVICE CARD

MEASURE ABSOLUTE PRESSURES

with SPEED and PRECISION

With Wallace & Tiernan Aneroid Dial Indicators you get precision and fast response in all types of absolute pressure work.

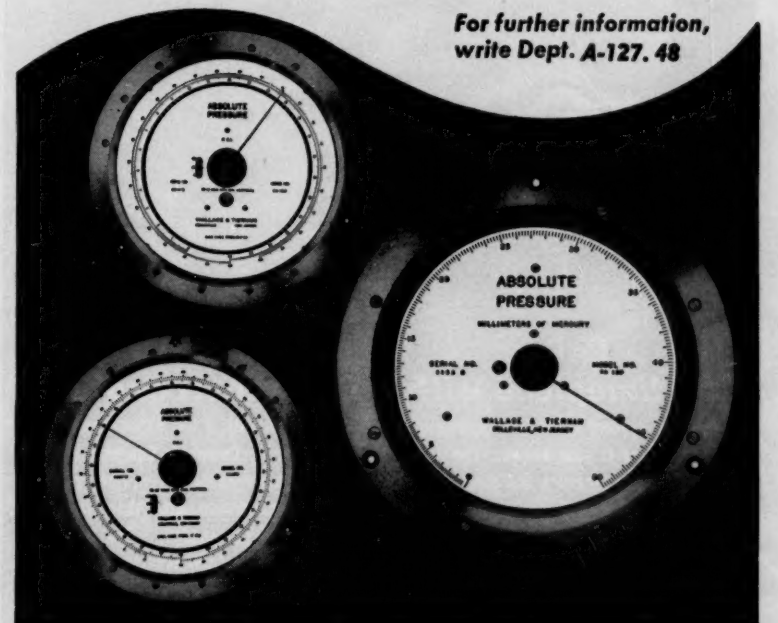
W&T Precision Indicators have many uses in research and development engineering. One is ideal for calibrating pressure transducers; another, for checking the calibration of flight instruments and ground support equipment. These instruments also keep constant check on continuous production-line work.

A W&T Absolute Pressure Gauge on the job means:

- ★ Accuracy 0.1% to 0.33%
- ★ Sensitivity 0.01% to 0.2%
- ★ Range 0.1-20 mm Hg to 0-500 p.s.i.a
- ★ No corrections
- ★ Light weight, small size

The accuracy of W&T Absolute Pressure Indicators approaches that of liquid columns... higher sensitivity assures faster response... large dial gives quick reading.

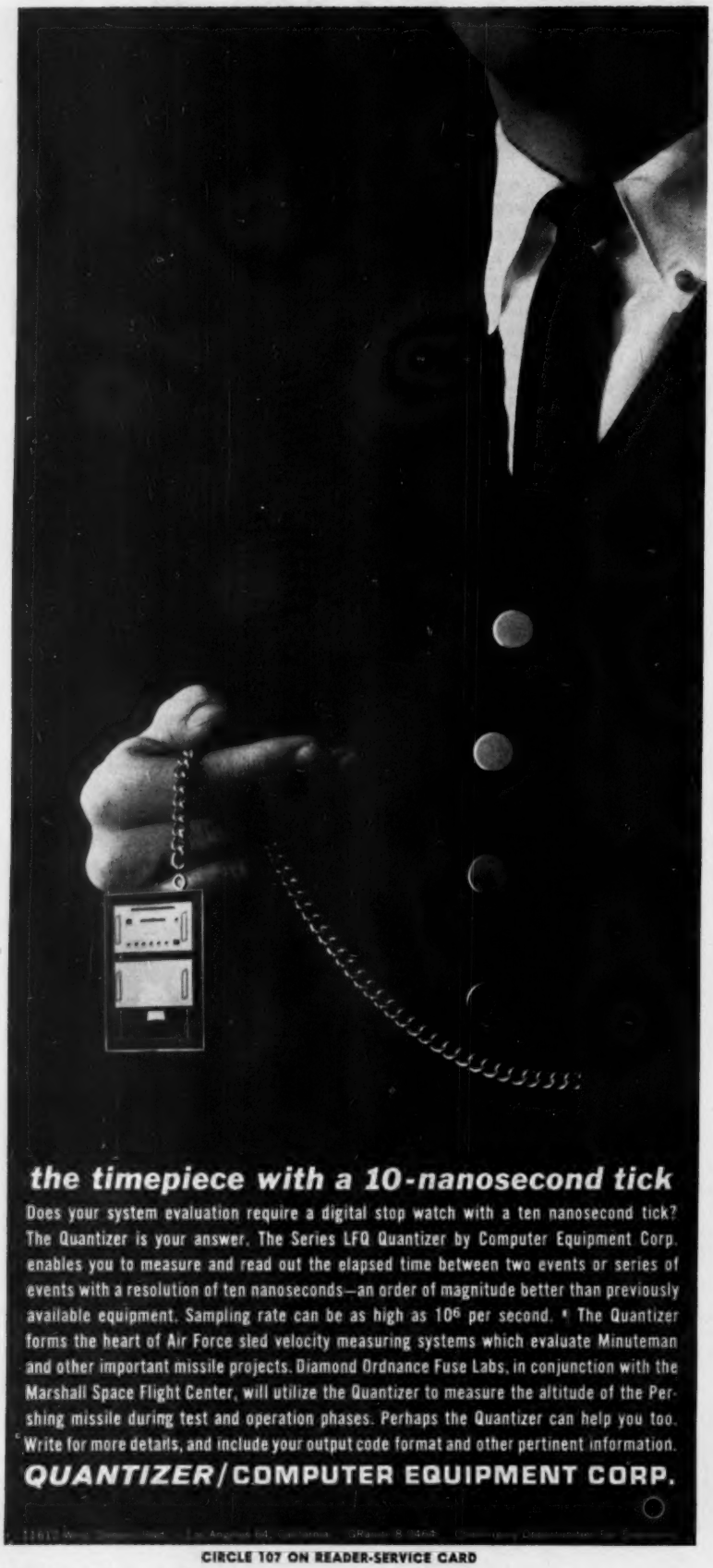
For further information, write Dept. A-127. 48



WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CIRCLE 106 ON READER-SERVICE CARD


the timepiece with a 10-nanosecond tick
Does your system evaluation require a digital stop watch with a ten nanosecond tick? The Quantizer is your answer. The Series LFQ Quantizer by Computer Equipment Corp. enables you to measure and read out the elapsed time between two events or series of events with a resolution of ten nanoseconds—an order of magnitude better than previously available equipment. Sampling rate can be as high as 10^6 per second. The Quantizer forms the heart of Air Force sled velocity measuring systems which evaluate Minuteman and other important missile projects. Diamond Ordnance Fuse Labs, in conjunction with the Marshall Space Flight Center, will utilize the Quantizer to measure the altitude of the Pershing missile during test and operation phases. Perhaps the Quantizer can help you too. Write for more details, and include your output code format and other pertinent information.
QUANTIZER/COMPUTER EQUIPMENT CORP.

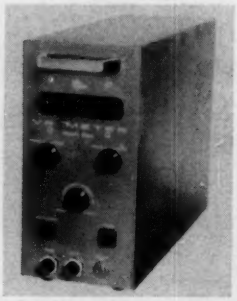
CIRCLE 107 ON READER-SERVICE CARD

RELIEF VALVE

New 5300 Series Relief Valve operates from 850 to 7200 psi, from −40° to 200°F; provides dead tight sealing to well above 95% of preset cracking pressure. Design permits system back pressure on poppet to increase its lift and provide maximum flow characteristics.—*Circle Seal Products Co., Inc.*, 2181 *E. Foothill Blvd., Pasadena, Calif.*

CIRCLE 261 ON READER-SERVICE CARD

VOLTMETER



New Model 2100 explosion-proof Digital Voltmeter withstands 50-G shock, is for use in missile fueling and critical environments formerly "off-limits" for digital voltmeters. Attenuator accuracy and bridge linearity are 0.003%; noise rejection (60 cps) is 80 db.—*Cubic Corp.*, 5575 *Kearny Villa Rd., San Diego* 11, *Calif.*

CIRCLE 262 ON READER-SERVICE CARD

SLIP-CLUTCHES AND BRAKES

New line of mechanical slip-clutches and brakes are designed for continuous slip, feature applications in tensioning and servomechanisms.—*Machine Components Corp.*, 39 *Fair Lane, Jericho, L. I., N. Y.*

CIRCLE 263 ON READER-SERVICE CARD

TUBE FITTINGS

New Ridg-lok tube fittings are machined from type 316 stainless steel especially for corrosion resistant service. Size range is 2 thru 16: for tubing of ⅛" thru 1" OD.—*Parker Fittings & Hose Div., Parker-Hannifin Corp.*, 17325 *Euclid Ave., Cleveland* 12, *Ohio.*

CIRCLE 264 ON READER-SERVICE CARD

MAGNETIC AMPLIFIER

New Model Fl low level magnetic amplfiier has power gain of 3,000,000 and requires no preamplification. Delivers 1 watt of dc power to standard aircraft relay when controlled by only a few microwatts of dc or ac power. PICO Bulletin 260.—*Polyphase Instrument Co., Bridgeport, Penna.*

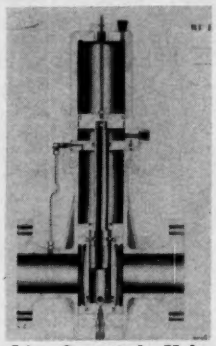
CIRCLE 265 ON READER-SERVICE CARD

ULTRASONIC TESTER

New Model 424-D Immerscope for ultrasonic nondestructive testing of plates, ingots, pipe, also tests reasonably elastic materials such as glass, hard rubber and ceramics. Features include variable pulse repetition rate, high-speed flaw-alarm circuit, built-in recorder output circuits and video delay circuit.—*Princeton Div., Curtiss-Wright Corp., Box* 110, *Princeton, N. J.*

CIRCLE 266 ON READER-SERVICE CARD

LINE-OPERATED VALVE



New Line-Operated Valve (500, 1500, and 3,000 psi) operates by line pressure alone or by normal pneumatic, hydraulic and electric systems. Seal is leakproof as sealing pressure is proportional to and directly opposes line pressure.—*KeXplore, Inc., Box* 22238, 3795 *Richmond Ave., Houston* 27, *Texas.*

CIRCLE 267 ON READER-SERVICE CARD

REGULATORS

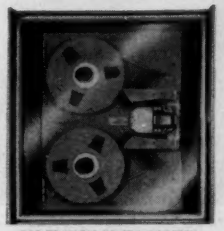
New Series 200 Regulators give performance of 2-stage regulator with simplicity and economy of single valve. Output pressures not affected by varying inlet pressure; flow capacity not restricted by extra valving. Gages unaffected by overpressure.—*Kim Products, Inc., Box* 1288, *Lexington, Ky.*

CIRCLE 268 ON READER-SERVICE CARD

OVER 100 BILLION BITS WITHOUT A DROPOUT !

RELIABILITY

WITH POTTER HIGH DENSITY RECORDING



906 II HIGH SPEED DIGITAL MAGNETIC TAPE HANDLER

TYPICAL CAPABILITIES OF POTTER HIGH DENSITY SYSTEMS

High Density Systems by Potter can include such outstanding characteristics as:

RELIABILITY: Transient error rate . . . 1 in 10^7 to 10^8 max. at 1500 ppi. Permanent error rate . . . 1 in 10^8 to 10^9 max. at 1500 ppi. Reread time to recover transient errors . . . less than .005% of "on-line" time at 1500 ppi

BIT DENSITIES up to 2,000/inch

TAPE SPEED up to 150 ips

NUMBER OF CHANNELS up to 20 per inch of tape width

INTERCHANNEL TIME DISPLACEMENT Less than 0.2 microsecond at buffer output

INTERBLOCK GAP May be as short as 0.3"; 0.75" typical for dual read/write operation at 100 ips

ERROR DETECTION Parity channel provides single error detection

ERROR CORRECTION Single parity channel makes possible single error correction

AND MANY OTHERS write for details

For more than 40 hours of continuous operation, Potter High Density systems have recorded 100 billion bits without a single dropout. And — they've done it at the fantastic rate of 240,000 decimal characters per second. Only with the revolutionary new recording technique do you get this combination of extreme capacity with ultimate reliability.

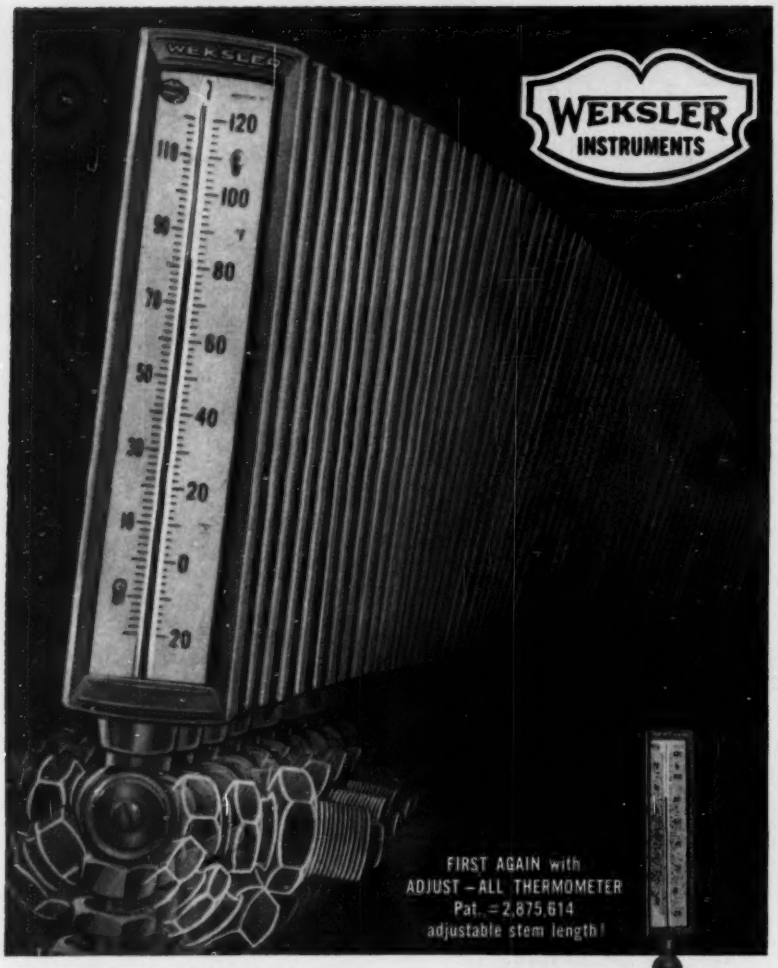
In the 40-hour test, less than 2 seconds re-read time were required to recover information lost through transient error. More than 20,000 passes of the tape can be made without losing information or significantly increasing the reading error rate.

Tested and proven in computer systems, Potter High Density Recording is presently available in the Potter 906II High Speed Digital Magnetic Tape Handler, and will be available in other Potter Tape Systems.

Write today for details on how High Density Recording can be applied to your data handling problem.

POTTER INSTRUMENT COMPANY, INC. • SUNNYSIDE BOULEVARD, PLAINVIEW, NEW YORK

CIRCLE 8 ON READER-SERVICE CARD



A MILLION *Adjust-Angle* THERMOMETERS AGO

...takes us back thirteen years, to U.S. Patent No. 2,524,894 awarded to **Weksler.** Until a few months ago, Weksler was the **only** adjust-angle thermometer you could buy. Today you have a choice from several different manufacturers who are in first model production of this remarkable instrument.

Thirteen years experience with a precise instrument represents a world of know-how...a decisive consideration in your **choice** of Weksler!

NEW WEKSLER ADJUST-ANGLE INDUSTRIAL THERMOMETERS, COMPLETELY REDESIGNED, ARE FULL 2-INCH WIDTH... EASY READING... HIGHEST ACCURACY IN ANY RANGE YOU DESIRE. 7- 9- 12-INCH SCALE SIZES, PLUS EXCLUSIVE 5" SCALE SIZE!

Write for Bulletin AA-60

WEKSLER INSTRUMENTS

"ORIGINATORS OF WORLD RENOWNED ADJUST-ANGLE THERMOMETERS"

WEKSLER INSTRUMENTS

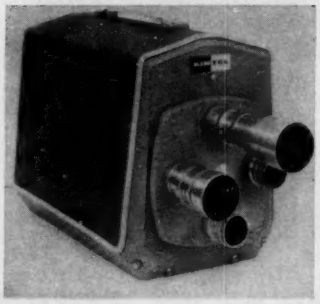
CORPORATION

195 EAST MERRICK ROAD, FREEPORT, L. I., N. Y.

Indicating and Recording Instruments for Temperature, Pressure and Humidity

CIRCLE 108 ON READER-SERVICE CARD

CLOSED-CIRCUIT TV



New 20/20 self-contained closed-circuit TV Camera has video bandwidth of 8 Mc, permitting full 650-line horizontal resolution with any high quality standard TV monitor; resolution limited solely by video amplifier in home TV receiver.—*Kintel Div., Cohu Electronics, Inc.,* 5725 *Kearny Villa Rd., Box* 623, *San Diego* 12, *Calif.*

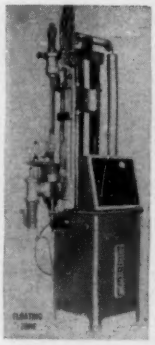
CIRCLE 269 ON READER-SERVICE CARD

HIGH-SPEED COUNTER

New high-speed Sodeco Type 4TiF6EM counting unit for speeds up to 250 impulses/sec consists of Dekatron tube, transistorized pulse shaper-amplifier, and Sodeco Totalizing counter.—*Landis & Gyr, Inc.,* 45 *W.* 45 *St., New York* 36, *N. Y.*

CIRCLE 270 ON READER-SERVICE CARD

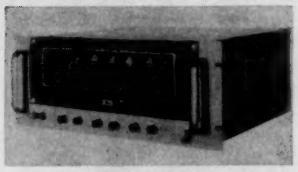
FLOATING ZONE/CRYSTAL PULLING FIXTURE



New Model HCP-D dual-purpose fixture for crystal pulling and floating zone applications for use with high frequency induction heating generator consists of basic unit with traverse mechanism and all controls including controls for operation of induction heating generator, and floating zone and crystal pulling attachments.—*Lepel High Frequency Laboratories, Inc.,* 55 *St.* & 37 *Ave., Woodside, N. Y.*

CIRCLE 271 ON READER-SERVICE CARD

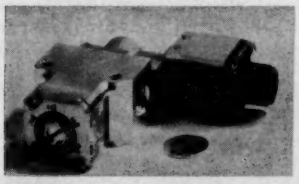
TIME GENERATOR



New solid-state Model 320 digital Time Generator for system control and synchronization, or for time correlation among diverse data acquisition and logging devices, uses 1-kc tuning-fork oscillator to assure time-base accuracy of 0.005%, generate timing markers at 0.001, 0.01, 0.1, and 1-sec intervals. Nixie display supplements 24-hr real-time decimal outputs.—*Lockheed Electronics Co., Box 446, Metuchen, N. J.*

CIRCLE 272 ON READER-SERVICE CARD

PRESSURE SWITCHES



New adjustable Deltadyne pressure and differential pressure switches provide reliable indication over range from 15 to 200 psid, withstand system pressures or overpressures up to 5000 psig. As differential pressure switches, they exhibit actuation pressures completely independent of absolute working pressure.—*Pall Corp., 30 Sea Cliff Ave., Glen Cove, N. Y.*

CIRCLE 273 ON READER-SERVICE CARD

LOW PRESSURE SWITCH

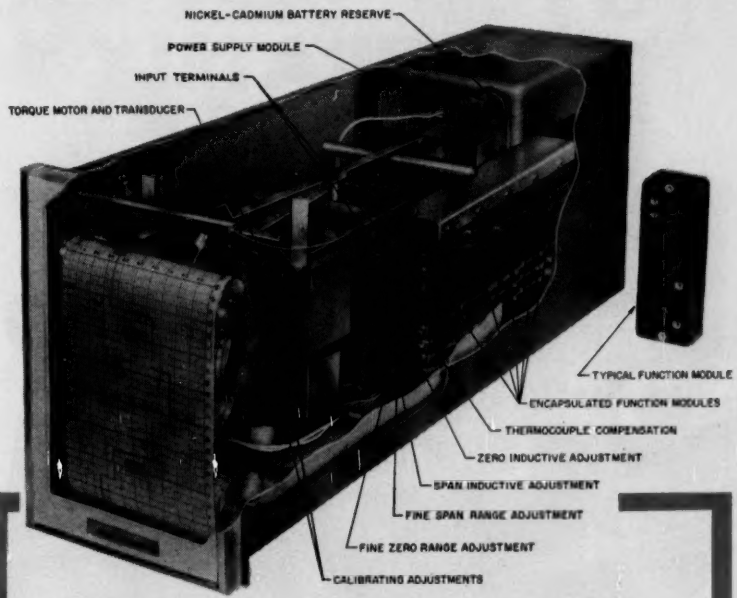
New Low Pressure Switch handles max set pressure of 7 psig, features deadband of 2" water, repeatable accuracy of ±0.5%. Ni Span C capsular-type sensing element reduces any change in pressure set point by thermal reaction over operating range, −65° to 300°F.—*Pamar Electronics Co., Inc., Subs. Hoke Inc., 1 Tenakill Park, Cresskill, N. J.*

CIRCLE 274 ON READER-SERVICE CARD

GENERAL KINETICS CONTROL SYSTEMS DE VAR

NEW TRANSISTORIZED MINIATURE RECORDER OFFERS

DC INPUT ISOLATION AND NOISE-FREE DC OUTPUT



The unique DE VAR potentiometer/receiver recorder is particularly suited for Strain-Gage Transducers, Thermocouples and Resistance Bulb Elements. The isolated input circuit rejects high common-mode noise without resorting to input balancing. The DC output signal is sufficiently noise-free to feed data loggers or computers. In addition, a low noise, high frequency carrier signal is available for drift-free operation of controllers and alarms.

- Exclusive inductive zero and span adjustment — continuously variable from 0-5 mv to 0-50 mv.
- Complete solid state circuitry — including unique transistor chopper.
- Battery reserve — eliminates costly down time.
- Full scale rectilinear writing — with 1, 2, or 3 pens.

Our Technical Bulletin R-301 describes the most advanced miniature recorder now available —

Write today

DE VAR SYSTEMS INC.

494 GLENBROOK ROAD
GLENBROOK, CONNECTICUT

A DIVISION OF GENERAL KINETICS CORPORATION

LICENSEE IN THE EASTERN HEMISPHERE:
DE VAR LIMITED • LONDON
A MEMBER OF THE ELLIOTT-AUTOMATION GROUP

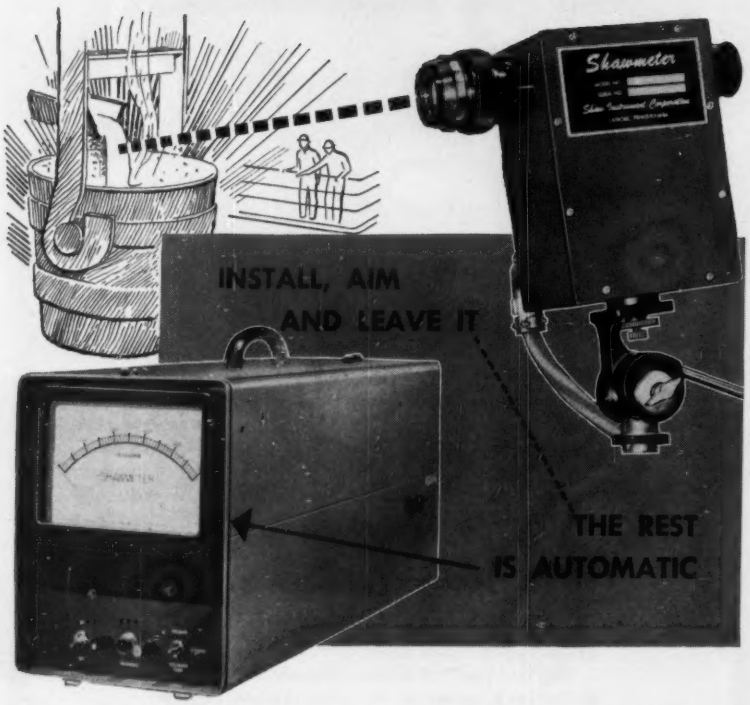
CIRCLE 110 ON READER-SERVICE CARD

Measure High Temperatures

EASILY, ACCURATELY

with the

SHAWMETER®



The SHAWMETER is an automatic, direct-reading, two-color pyrometer for indicating, recording or controlling temperatures up to 6500°F.

Measures the temperature of flowing metal, or of moving or stationary objects. No emissivity correction needed. Temperatures may be measured at a considerable distance from the object.

Accurate, sensitive, rugged. Write for complete details.

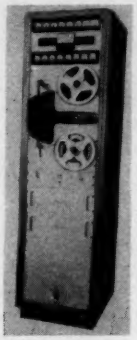
SHAW INSTRUMENT CORPORATION

CERAMIC-METAL SEALS • NUCLEAR and ELECTRONIC INSTRUMENTATION

P. O. Box L-46 Latrobe, Pennsylvania

CIRCLE 111 ON READER-SERVICE CARD

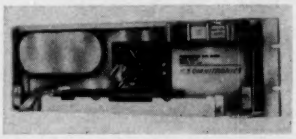
RECORDER/REPRODUCER



New Series T-1000 magnetic tape Recorder/Reproducers have as many as 20 channels for simultaneous recording of voice-frequency program material, variety of tape speeds and capacities, recording and reproducing time ranges from 8 to 24 hr. Features include: plug-in transistorized circuitry, dual-flywheel flutter-free drive, straight-line threading, "fail-safe" sensing system.—*Magnasync Corp.*, 5546 *Satsuma Ave., North Hollywood, Calif.*

CIRCLE 275 ON READER-SERVICE CARD

PHOTOELECTRIC TAPE READER



New Model PTR-7 Photoelectric Tape Reader uses light-chopper wheel and a-c coupled amplifiers to assure stability, better signal-to-noise ratio in reading more translucent tapes. Unit reads standard tape widths at speeds to 100 ips. Bulletin PTR-7.—*Omnitronics, Inc.*, 511 *N. Broad St., Phila. 23, Pa.*

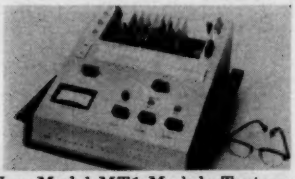
CIRCLE 276 ON READER-SERVICE CARD

CARRIER-DEMODULATOR

New 3¼" x 5¼" x 3" Model CD10 Carrier-Demodulator for use with PACE Variable Reluctance Pressure Transducers, provides d-c output signal for recording and control in d-c systems, operates on 95-125 v, 60 cps at 5 w. Stability is ±½% full scale. —*Pace Engineering Co.*, 13035 *Saticoy St., North Hollywood, Calif.*

CIRCLE 277 ON READER-SERVICE CARD

DIGITAL CIRCUIT ANALYZER



New Model MT1 Module Tester permits dynamic tests under marginal conditions of input pulse amplitude, duration, rise time, etc. on solid-state digital circuit modules and PB 250 computer modules. Flexibility achieved by generating test signals with standard plug-in modules and routing them through operational test connector sockets and adapter to module under test.—*Packard Bell Computer, Subs. Packard Bell Electronics, 1905 Armacost Ave., Los Angeles 25, Calif.*

CIRCLE 278 ON READER-SERVICE CARD

4PDT RELAY

New long-life KHP Series 4PDT Relays are rated for loads ranging from dry circuit up to 3 amps at 30-v dc or 115-v ac resistive; coil operating voltages range from 6-110 v dc. Time values of 15 msec max pull-in, 5 msec max drop-out, 3 msec max transfer time on pull-in and approx 1 msec transfer time on drop-out.—*Potter & Brumfield, Princeton, Ind.*

CIRCLE 279 ON READER-SERVICE CARD

TAPE SIMULATOR

New Model PS-250-L continuous tape loop Simulator provides 50 or more channels for repetitive playback of data. Simulator uses 1" tape with 33 tracks in standard IRIG head configuration; bandwidth capabilities extend from dc to 5 kc at tape speed of 15 ips.—*Precision Instrument Co., 1011 Commercial St., San Carlos, Calif.*

CIRCLE 280 ON READER-SERVICE CARD

G-A CUSHIONED SOLENOID OPERATED VALVE

Where remote control valve operation is desired, specify and use the G-A Cushioned Solenoid Operated Valve that automatically opens or closes on any type of electrical impulse. The operating sequence—whether on open or closed circuit—can be made to suit your requirements. Sizes 2" to 36"

Bulletin W-7A has the complete story.

GOLDEN ANDERSON Valve Specialty Company

1286 RIDGE AVENUE, PITTSBURGH 33, PA.

Designers and Manufacturers of VALVES FOR AUTOMATION

CIRCLE 112 ON READER-SERVICE CARD

FUNCTION GENERATOR

New SF-1 Arbitrary Function Generator whose drum position, or X-axis, is positioned according to a voltage input to the servo amplifier, Type A-1, has a voltage output proportional to the ordinate $Y = f(x)$ of the chart drum curve. This curve can either be drawn with special conductive ink on standard 8½" x 11" graph paper, or can be a printed circuit on flexible plastic. Response time of drum position (X-axis) is approximately one sec, zero to full scale.—*Alabama Automation Corp., Box 875, Huntsville, Ala.*

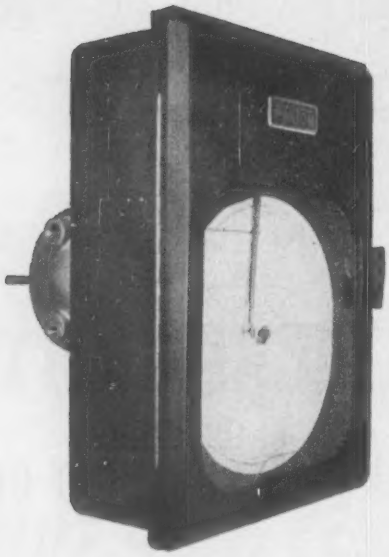
CIRCLE 281 ON READER-SERVICE CARD

HYDRAULIC CELLS

New line of hydraulic cells, Model EC-RB, meets conditions of chemical and food processing industries in weighing tanks and bins. Cells are based on the familiar hydraulic piston and cylinder principle and also utilize the "rolling ball" head construction which permits easy alignment of the loading head and allows for expansion or contraction of the tank or bin without subjecting the cell to any harmful cross loads. Bulletin 601.—*A. H. Emery Co., New Canaan, Conn.*

CIRCLE 282 ON READER-SERVICE CARD

THE FLOW RECORDER YOU CAN COUNT ON



Absolute dependability, under the most demanding operating environments—that's the promise and the performance of the Barton 202A flow recorder. Thoroughly proven in the gas production fields, the 202A is enjoying ever-increasing popularity in gas transmission and distribution systems. It is compact and ruggedly built, not subject to the usual frailties of such a precise instrument; it has built-in overrange protection, which allows it to maintain calibration under wide pressure fluctuations; it is immune to condensate problems, making it ideal for application in all geographical areas. A recently added bonus: the 202A can be fitted with the new Barton chart changer which allows the instrument to record continuously and unattended, for up to 16 days, using a fresh chart each day. For complete information and specifications on the 202A flow recorder, request Bulletin 202A-1.

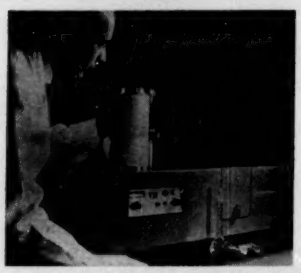
BARTON

RECORDER-INTEGRATORS/CONTROLLERS/DIFFERENTIAL PRESSURE INDICATORS/PNEUMATIC TRANSMITTERS/FLOW SWITCHES

BARTON INSTRUMENT CORPORATION • MONTEREY PARK, CALIFORNIA

CIRCLE 113 ON READER-SERVICE CARD

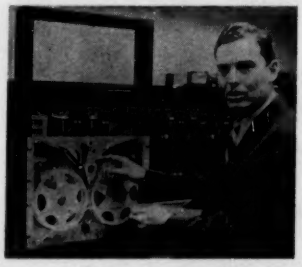
UV SPECTROPHOTOMETER



New Model 202 ultraviolet-visible Spectrophotometer features optical null principle, automatic gain control system, 60° fused silica prism for high dispersion. Wavelength accuracy ±0.5 millimicrons, UV; ±1.0 millimicron, visible.—*Perkin-Elmer Corp., Norwalk, Conn.*

CIRCLE 283 ON READER-SERVICE CARD

HIGH-SPEED TAPE READER



New Model 300 R Photoelectric Tape Reader uses printed motor to advance paper tape asynchronously at rates to 300 lines/sec without use of brakes, clutches or pinch rollers. Eliminates mechanical members in capstan and reel drives.—*Photocircuits Corp., 31 Sea Cliff Ave., Glen Cove, N. Y.*

CIRCLE 284 ON READER-SERVICE CARD

HIGH-DENSITY RECORDING

New High Density Recording System records magnetically on 10½" reel of 1" tape "approx 11 times amount of digital data recorded by conventional systems." Provides reliability despite data transfer rates as high as 360,000 alpha-numeric characters/sec, and at packing densities up to 1500 bits/in.—*Potter Instrument Co., Inc., Plainview, L. I., N. Y.*

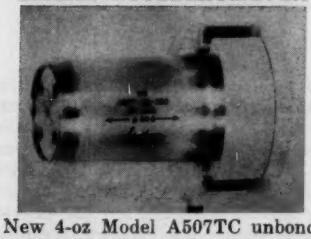
CIRCLE 285 ON READER-SERVICE CARD

RESISTANCE BRIDGE

New 10-channel Triple-bridge (variation of basic Wheatstone bridge) for use in temp measurement with variable resistance temp probes suppresses lead resistances both at null and when unbalanced. Typically, when leads vary from 0 to 5 ohms collectively or individually, effect does not exceed 0.1% of full scale. Bulletin 86012.—*Rosemount Engr. Co.*, 4900 *W.* 78 *St., Minneapolis* 24, *Minn.*

CIRCLE 286 ON READER-SERVICE CARD

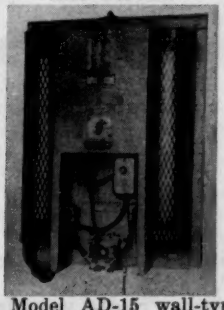
LINEAR ACCELEROMETER



New 4-oz Model A507TC unbonded strain-gage Linear Accelerometer is temp-compensated and gas-damped, has ranges from ±25g through ±100g, provides relatively constant damping from −65° to +250°F (no heater jacket required). Excitation is 5-v dc or ac (rms) through carrier frequencies; full-scale open circuit output approx ±20 mv at 5 v.—*Statham Instruments, Inc.*, 12401 *W. Olympic Blvd., Los Angeles* 64, *Calif.*

CIRCLE 287 ON READER-SERVICE CARD

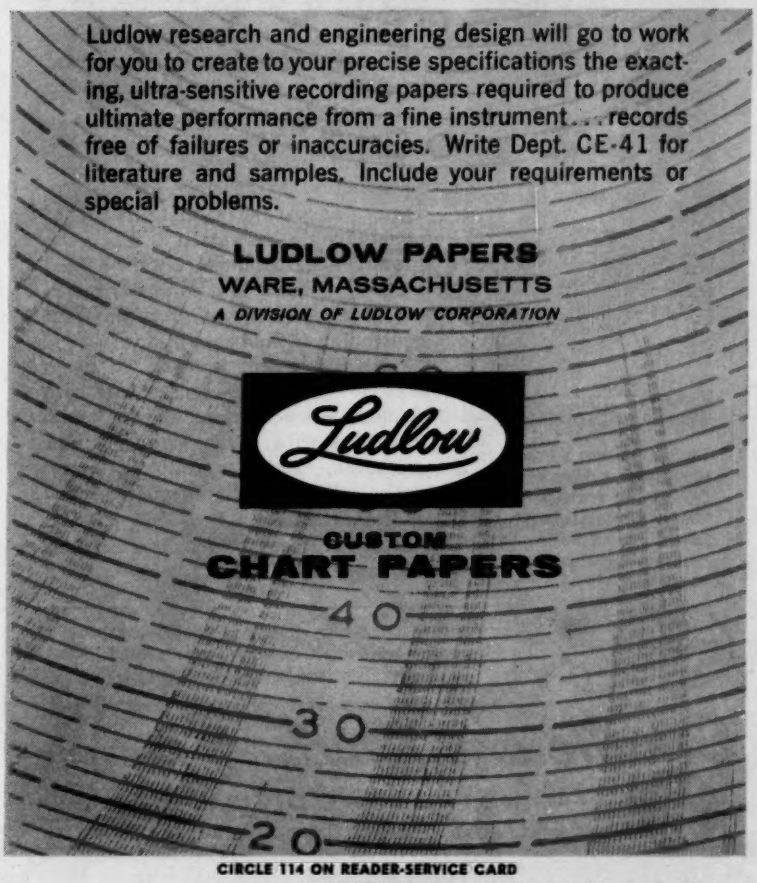
AIR DRYER



New Model AD-15 wall-type Air Dryer for instruments and pneumatic controls uses desiccant dehydrator, minimum valves and solenoids, dual tower design. Operating air pressure 100 to 125 psig saturated up to 100°F, dry air outlet adjustable 0 to 30 psi, output at 10 psi 6 scfm, dew point −60°F.—*S & G Mfg. Corp., Box* 1309, *New Orleans* 10, *La.*

CIRCLE 288 ON READER-SERVICE CARD

LUDLOW
SPECIALLY-DESIGNED
CUSTOM PAPERS
for your
special
RECORDING INSTRUMENT
Sophisticated instruments that chart critical variables demand sophisticated recording papers. That's why more and more recording instrument manufacturers are turning to Ludlow, patent holders of the first non-wax thermal and pressure sensitive chart papers.


Ludlow research and engineering design will go to work for you to create to your precise specifications the exacting, ultra-sensitive recording papers required to produce ultimate performance from a fine instrument... records free of failures or inaccuracies. Write Dept. CE-41 for literature and samples. Include your requirements or special problems.
LUDLOW PAPERS
WARE, MASSACHUSETTS
A DIVISION OF LUDLOW CORPORATION
Ludlow
CUSTOM
CHART PAPERS
40
30
20

CIRCLE 114 ON READER-SERVICE CARD

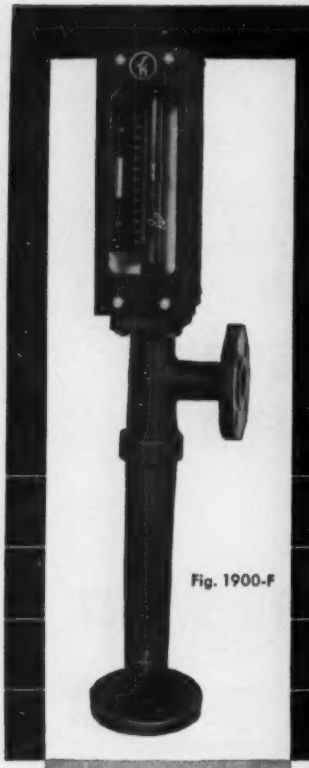
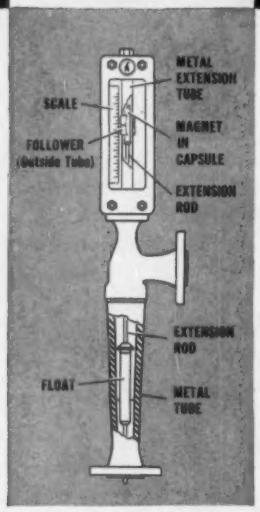


Fig. 1900-F

Use this
METAL-TUBE ROTAMETER
to measure Rate-of-Flow of

HAZARDOUS FLUIDS
HIGH PRESSURE FLUIDS
STEAM



The float extension, see above, contains a magnet. When the magnet moves in the extension tube, the follower (outside the extension tube) follows. The follower position, in relation to the meter scale, indicates rate of flow.

SK Metal-Tube (Armored) Rotameters were specially designed for measuring the rate of flow of hazardous fluids, fluids under high pressures, and steam in chemical, petroleum, and other industrial plants.

These SK Rotameters combine accuracy with sound design and sturdy construction to provide an easy-to-apply, easy-to-use instrument of considerable versatility. For, the Metal-Tube Rotameter can be used for direct reading or it can be arranged for remote indicating, recording, or controlling of fluid rate-of-flow.

This instrument is made for tough service—has a tapered metal tube with flanged connections as shown, metal extension tube, float with magnetic extension, magnetic follower, meter scale, and a sturdy "Safeguard Type" indicator case.

Get complete details. Write to SK for new Bulletin 19A.

QUICK DELIVERY FROM STOCK

For Immediate Delivery, Standard SK Jet Ejectors, Rotameters, and Flow Indicators are stocked in Cornwells Heights (Phila.), Pa., Houston, Texas, and San Francisco, Calif.

Schutte and Koerting COMPANY
INSTRUMENT DIVISION
2225 STATE ROAD, CORNWELLS HEIGHTS, BUCKS COUNTY, PA.

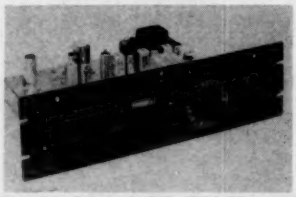
CIRCLE 115 ON READER-SERVICE CARD

SIGHT FLOW INDICATOR

New Flo-Eye Indicator reveals flow, direction, and condition of fluid inside pipeline through double sight glasses. Prevents damage, conserves power, avoids shutdowns.—*Dept. M-V, Schutte and Koerting Co., Cornwells Hts., Bucks County, Pa.*

CIRCLE 289 ON READER-SERVICE CARD

FM TUNER



New Model 310-DR FM Tuner has 2-μv sensitivity ("higher than any other tuner on market"). Distortion less than 0.5%, frequency response $\pm$0.75 db from 20 cycles to 75 kc. "Dynamic interstation noise suppressor and exclusive electronic relay provide simple yet effective diversity reception system for unusually high signal quality under extremely difficult conditions."—*H. H. Scott Inc.*, 111 *Powdermill Rd., Maynard, Mass.*

CIRCLE 290 ON READER-SERVICE CARD

PHOTORELAY SYSTEM

New Model 8P12 System consists of Photorelay Receiver and separate, matching Light Source, will switch 3-amp, 120-v resistive load at least two times a second with units up to 20′ apart, requires no wiring.—*Sigma Instruments, Inc.*, 170 *Pearl St., S. Braintree* 85, *Mass.*

CIRCLE 291 ON READER-SERVICE CARD

LEVEL TRANSMITTER

New Type 115S liquid-level measuring device is applicable to all types of liquid, and is especially suited for heavy, viscous materials or slurries. It can be used to measure, indicate or record on static head pressure ranges of 2″ W.C. to 65 psi.—*Fisher Governor Co., Box* 307, *Marshalltown, Iowa.*

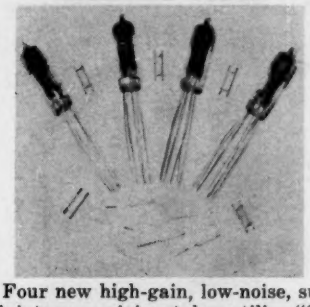
CIRCLE 292 ON READER-SERVICE CARD

POWER SUPPLY

New Portable QCR36-30 Power-Supply has output range of 0-36 v at 4 amp, features silicon control rectifier input circuit which limits dissipation in main regulator circuit and provides electronic protection against excessive current and voltage transients. Load protected by new electronic circuit-breaker.—*Sorensen & Co., Inc., Richards Ave., South Norwalk, Conn.*

CIRCLE 293 ON READER-SERVICE CARD

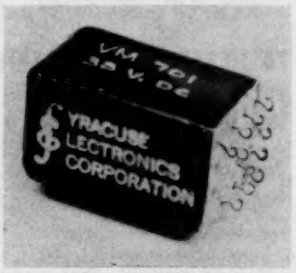
RECEIVING TUBES



Four new high-gain, low-noise, subminiature receiving tubes utilize "Sarong" cathodes and strap frame grids. Two are medium mu UHF double triodes, two are high mu UHF triodes; all feature superior performance compared with prototypes.—*Sylvania Electric Products Inc., 730 Third Ave., New York 17, N. Y.*

CIRCLE 294 ON READER-SERVICE CARD

VOLTAGE MONITOR

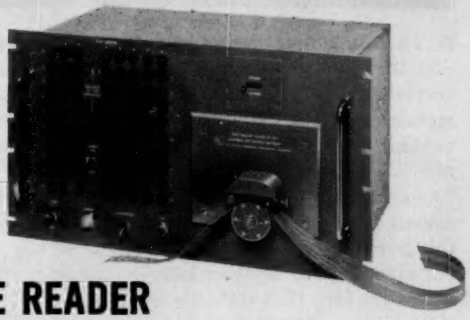


New solid-state VM 701 (2-amp, DPDT) and VM 702 offer small size (1 cu. in), repeatability better than 0.01% under fixed conditions, low power drain, and high shock. VM 702 solid-state output drives relay solenoid. Both units in any voltage, ac or dc, single or double ended.—*Syracuse Electronics Corp., Box 566, Syracuse 1, N. Y.*

CIRCLE 295 ON READER-SERVICE CARD

HOLE HEARTED

IS THE JOB DONE BY EECO'S LONG-LIVED TP-401 PUNCHED-TAPE READER



Looking for improved tape-ability? For sequencing automatic testing in ground support, or for the control of simulation devices, this ruggedized punched tape reader makes better, more reliable contact than any other reader because of unique springloaded pins.

Reads 80 bits per frame at 6 frames per second. Searches at 12 ips. Includes neon-lamp verifier panel for quick checking of new tapes. Uses 1" paper or tough mylar tape with standard eight-level 0.1" punching. Manual or remote stepping, 4-digit frame counter with reset, other desirable features.

Costs only $1,620 f.o.b. Santa Ana. (Or $1,490 for model TP-402 without verifier.) Send for Data File TP-401.

EECO also makes these other punched tape readers for special applications:

Model TP-813 13-channel programmer for airborne use. $990.

Model TP-201A 80-bit bi-directional programmer. $1,160.

Model TP-860 8-channel time base programmer. $875.

Automation Division
Electronic Engineering Company *of California*
1601 EAST CHESTNUT AVE. SANTA ANA, CALIF. KIMBERLY 7-5501
TWX: SANTA ANA CAL 5263

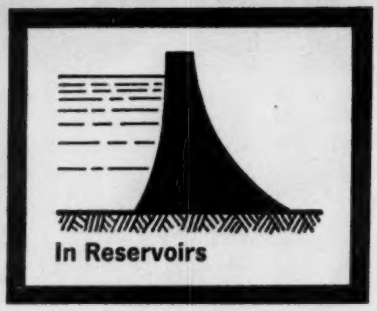
Several important career opportunities are now open in EECO's engineering department. Call or write Merl Perkins.

EE 6-18

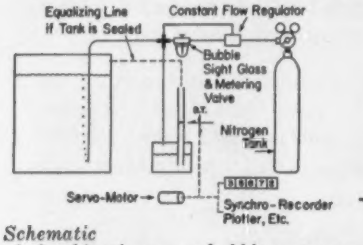
CIRCLE 116 ON READER-SERVICE CARD

A significant new announcement...

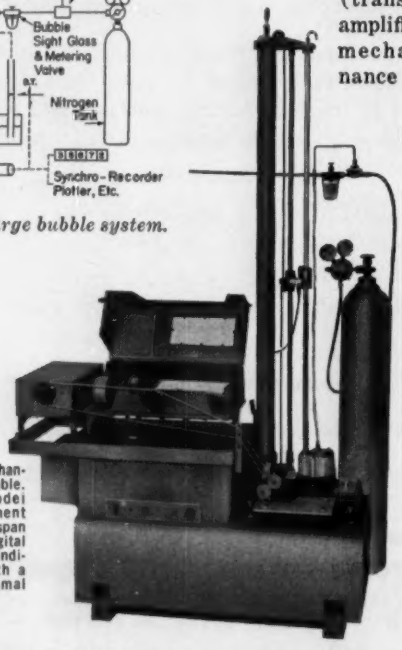
Precision Measurement of Any Liquid



■ This technique has proven to be of remarkable accuracy, utility and reliability—with any liquid; water, high-temperature products, petroleum derivatives, radio-active materials, the most active chemicals and molten metals. ■ Combination of the Exactel Servomanometer with the purge bubbler principle is resolving problem measurement situations. The technique is relatively new but thoroughly proven over the past three years. The process is one of weighing, rather than sensing surface level. Errors caused by temperature change, absorbed gases, etc., are eliminated. For this purpose the Servomanometers generally employ 32" or 60" Hg range, but other liquids or other ranges may be used. ■ The instrument's accuracies are such that systems now in use have been readily approved for billing purposes; so accurate, in fact, as to practically defy calibration. ■ The systems are simple, reliable and economical. Except for minor lubrication and tube-cistern cleaning at approximately annual intervals, Exactel Tank Gaging systems are expected to provide **70 to 100 thousand hours of service** with no electronic (transistorized servo-amplifiers are used) or mechanical maintenance in this service.



Schematic of plumbing for purge bubble system.

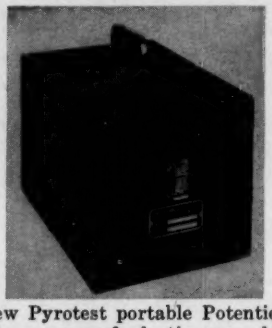


Several alternate data handling options are available. Illustrated is 60" Model 1560IN-D for measurement of tank level with multispan mechanical recorder, digital encoder and counter to indicate level directly with a least unit to five decimal places.

EXACTEL INSTRUMENT COMPANY
185 Evelyn Avenue • Mountain View, California • YO 8-6558

CIRCLE 117 ON READER-SERVICE CARD

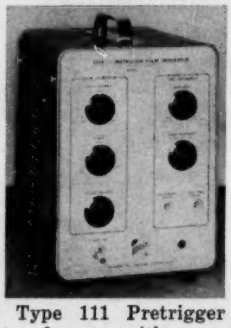
PORTABLE POTENTIOMETER



New Pyrotest portable Potentiometer in mar-proof plastic case checks thermocouple-actuated indicators, controllers, recorders; measures temp, and checks other potentiometers. Standard equipment includes 9 interchangeable, direct-reading scales for use with any type thermocouple.—*Technique Associates, 1413 N. Cornell, Indianapolis 2, Ind.*

CIRCLE 296 ON READER-SERVICE CARD

PULSE GENERATOR



New Type 111 Pretrigger Pulse Generator for use with conventional oscilloscopes or specialized electronic equipment, provides both output and pretrigger pulses. Output pulses have ±5-v amplitude, duration of 2 nanoseconds (min) and 100 nanoseconds (max) at low repetition rates—decreasing to 20 nanoseconds at 100-kc repetition rate.—*Tektronix, Inc., Box 500, Beaverton, Oregon.*

CIRCLE 297 ON READER-SERVICE CARD

TC REFERENCE JUNCTION

New 115-v and 28-v Miniature Multi-Channel Thermocouple Reference Junction for airborne and test cells replaces conventional ice bath as reference temp for thermocouples; features precision and regulation to 3°F or better, uses multiple temp controls. Offers field-adjustable or fixed reference temp with built-in resistance temp monitor. Bulletin 7.—*Aero Research Instrument Co., 315 N. Aberdeen St., Chicago 7, Ill.*

CIRCLE 298 ON READER-SERVICE CARD

TEMPERATURE SENSORS

New Temperature Sensors, Delta-Couples, designed to indicate rapidly changing surface temperatures of steel structures over a wide range of pressure and temperatures, have either nickel-steel thermocouple junctions at either 0.0002" below the surface of interest for maximum response, or at 0.002" below the surface where abrasion is a consideration. Two basic models are available: Model S1 for extremely high pressures (100,000 psi transient) while Model S2 has a threaded body to facilitate installation.—*Advanced Technology Labs., 369 Whisman Rd., Mountain View, Calif.*

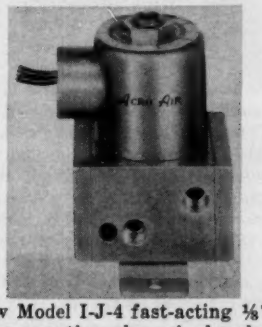
CIRCLE 299 ON READER-SERVICE CARD

MILLIVOLTMETER

New RF millivoltmeter Model 411A measures RF voltages from 1 mv to 10 v at frequencies up to 1000 Mc. Two linear voltage scales in a 1:3 ratio help eliminate scale reading errors and provide maximum voltage resolution. A db scale provides readings from −42 to +33.—*Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif.*

CIRCLE 300 ON READER-SERVICE CARD

PNEUMATIC VALVE



New Model I-J-4 fast-acting ⅛", 4-way pneumatic valve, single-solenoid operated, works with less than 10 psi and up to 150-psi line pressure. Valve has aluminum body, popper-type piston, no springs in main body (permitting full line air flow).—*Acro Air Associates, 16736 Foothill Blvd., San Leandro, Calif.*

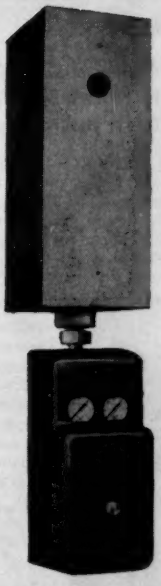
CIRCLE 301 ON READER-SERVICE CARD

VARIABLE TIME DELAY

New continuously Variable Time Delay Standard has infinitesimal resolution time, readability better than 50 millimicrosec, no time jitter, rise time essentially zero, bandwidth over 2000 mc, accuracy better than 1%. Maximum attenuation is 0.017 db at 100 mc, 0.68 db at 1000 mc, 0.85 db at 1500 mc.—*Ad-Yu Electronics Lab., Inc., 249-259 Terhune Ave., Passaic, N. J.*

CIRCLE 302 ON READER-SERVICE CARD

HIGH-PRESSURE FLOWS



BROOKS CAN METER THEM AS HIGH AS 100,000 PSI! Brooks rotameters work well under pressure. Right now there are several operating around the clock at 40,000 psi, in process lines ranging from ½ to 2 inches. Operation has been very satisfactory. Even on heavily pulsating flows. (The meters have built-in provision for pulsation damping. It is simple. And very effective.) ■ Brooks high-pressure meters can be supplied with either electric or pneumatic transmitting extensions. Both are compatible with most receiving instruments. Both use the Brooks magnetic position converter, the most reliable transducer of its kind. ■ If you have a high-pressure metering job, ask us about it. We can probably give you exactly what you need. And at a price somewhat lower than you'd expect to pay. Design Specification Sheet 3613 will give you more information.

BROOKS INSTRUMENT CO., INC.
5004 W. VINE ST. • HATFIELD • PENNSYLVANIA

Brooks Instrument Canada Limited, Scarborough, Canada • Brooks Instrument Company, S. A., Fribourg, Switzerland • Brooks Instrument Nederland, N. V., Veenendaal, Netherlands

SA 2360

CIRCLE 118 ON READER-SERVICE CARD

AC-DC INSTRUMENT CALIBRATION

to 0.25% Accuracy

Model 829A provides a single package method of maintaining plant-wide instrument accuracy at modest cost.

Full-scale calibration accuracy of 0.25% for both AC and DC meters over ranges from 0.25 millivolt to 2000 volts and 2 microamperes to 20 amperes is provided by this completely self-contained unit. AC calibrations can be performed from 50 to 400 cps., depending on line frequency used, or the Model 829A can be driven by an optional variable frequency power supply (see below).

The Model 829A is a comparison type calibrator, using horizontally mounted standard meters of high accuracy and dependability. Range switches and high voltage discharge circuits are safety interlocked, protecting the standard meters and the meter being tested from accidental overloading. Model 829A can be used effectively and safely by personnel not previously acquainted with instrument calibration techniques. Net price $3,150.

The most compact calibration system available is also mobile.

Photo inset shows the Model 829A secured with shock mounts on the RFL Model 10 Test Equipment Cart with the standard meters recessed into a drop-leaf work shelf. In the Cart is a Model 500 Variable Frequency Power Supply for line regulation and for supplying any frequency for calibration from 50 to 400 cps.

Performance is rigidly guaranteed. Prices are f.o.b. Boonton, N.J. and subject to change without notice.

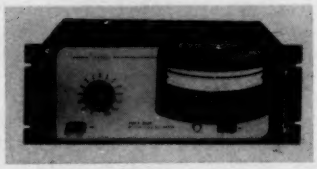
SEND FOR TECH. DATA

For additional information, including application data, write or phone DE 4-3100. Demonstrations available by local representatives.

Radio Frequency LABORATORIES, INC. Boonton, New Jersey, U.S.A.

CIRCLE 119 ON READER-SERVICE CARD

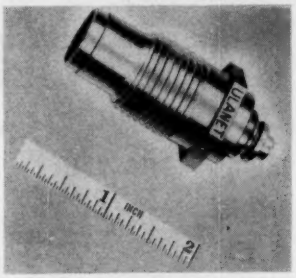
TRUE RMS VTVM



New Model 120-7 rack-mounted true RMS VTVM offers direct, instant readings of a-c voltages with accuracy of ¼% of full scale, uses special dynamometer movement to eliminate errors due to harmonic and spike distortions. Meter deflection directly proportional to square of current through dynamometer movement. Input impedance of 1 megohm, fundamental frequency response of 50-2000 cps.—*Trio Laboratories, Inc., Plainview, N. Y.*

CIRCLE 303 ON READER-SERVICE CARD

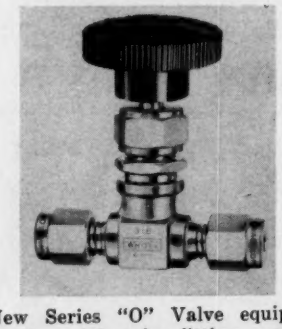
ALARM THERMOSTAT



New Model 265 Miniature Immersion Alarm Thermostat for use in liquid-cooled engines, oil-cooled transformers, etc. does not impede flow of circulating liquids, can be used with alarm devices, pilot lights, solenoids and relays. Contacts are of normally open type which close with rise in temp.—*George Ulanet Co.*, 413 *Market St., Newark* 5, *N. J.*

CIRCLE 304 ON READER-SERVICE CARD

MINIATURE VALVE



New Series "O" Valve equipped with Swagelok tube fitting connections for ⅛" O.D. tubing, in brass and type 316 stainless, has straight pattern, forged body 2¼" high. Pressure rating, 3000 psi at room temp; orifice, 0.080".—*Whitey Research Tool Co.*, 5525 *Marshall St., Oakland* 8, *Calif.*

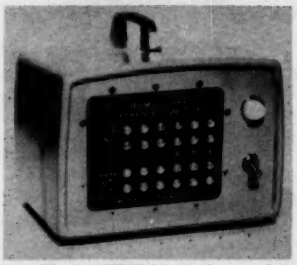
CIRCLE 305 ON READER-SERVICE CARD

RADIATION PYROMETER

New Pyrotron Radiation Pyrometer measures temps to 4000°F within ±1% of temp span. High signal output of 60 mv at 2200°F permits use of a-c type receiver-recorder up to 500′ away; built-in optical sighting system checks alignment.—*Bailey Meter Co.*, 1050 *Ivanhoe Rd., Cleveland* 10, *Ohio.*

CIRCLE 306 ON READER-SERVICE CARD

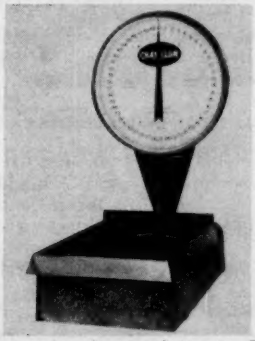
TC REFERENCE JUNCTION



New Model TRJ 3006 elevated temp Thermocouple Reference Junctions are basically stable devices designed around on-off type temp control system which operates on small temp differential. Cycling temp effect dampened by heat sink until temp variation is less than −1/6°F.—*Temptron, Inc.*, 7030 *Darby Ave., Reseda, Calif.*

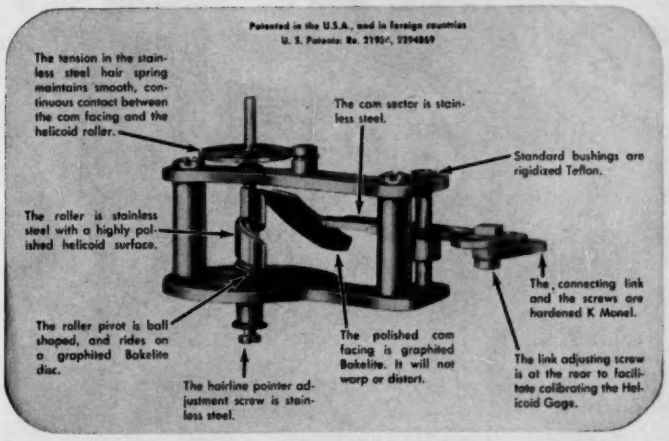
CIRCLE 307 ON READER-SERVICE CARD

PLATFORM SCALE



New corrosion-resistant Model ISBM bench-type Platform Scale in capacities of 50, 100 and 200 lb has stainless steel 13″ x 17″ platform, pivots and bearings, and 4-coat tin-lead undercoating. Iso-Elastic springs are temp compensated 0° to 150°F.—*John Chatillon & Sons*, 85 *Cliff St., New York* 38, *N. Y.*

CIRCLE 308 ON READER-SERVICE CARD


Patented in the U.S.A., and in foreign countries
U. S. Patents: Re. 21934, 2794869
The tension in the stainless steel hair spring maintains smooth, continuous contact between the cam facing and the helicoid roller.
The cam sector is stainless steel.
Standard bushings are rigidized Teflon.
The roller is stainless steel with a highly polished helicoid surface.
The connecting link and the screws are hardened K Monel.
The roller pivot is ball shaped, and rides on a graphited Bakelite disc.
The polished cam facing is graphited Bakelite. It will not warp or distort.
The link adjusting screw is at the rear to facilitate calibrating the Helicoid Gage.
The hairline pointer adjustment screw is stainless steel.

Exclusive Helicoid movement provides... *Sustained Accuracy... on the toughest jobs*

• Helicoid Gages have no gears, no teeth, reducing wear to an absolute minimum. No danger of fouling, either—rolling action of cam facing keeps contact surface clean. Helicoid Gages have been tested through 75,000,000 cycles, with virtually no wear or loss of accuracy, while conventional geared gages became useless after 500,000 cycles.

Helicoid Gages give *sustained* accuracy even when subjected to violent pressure pulsations or mechanical vibrations. Pointer can be set externally, without removing glass, and cannot be jarred out of position. Dial faces are easy to read, won't corrode or chip. A full range of Helicoid Gages is available for any application. Next time, specify Helicoid—the gage that *stays* accurate.

Bourdon Tubes won't Stretch, Leak, or Crack

Helicoid Bourdon tubes are made from seamless tubing, and are designed for maximum torque and minimum stress. At the factory, each tube is individually tested, overpressured, and stress relieved. Four materials—alloy steel, K Monel, stainless steel, and phosphor bronze—are available to meet applications ranging from tap water to almost any acid.

NEW! Solid-Front Safety Case Gives Added Protection

The new Helicoid solid-front case diverts the force of a burst in a backward direction, away from the operator. The force escapes by deforming, though not detaching, the back cover plate. Helicoid Gages are also available in phenol, acaloy flanged, acaloy flangeless, polished flangeless, round flush, polished flush ring, and square flush cases.

WRITE for details **Ask for Catalog DH-65**

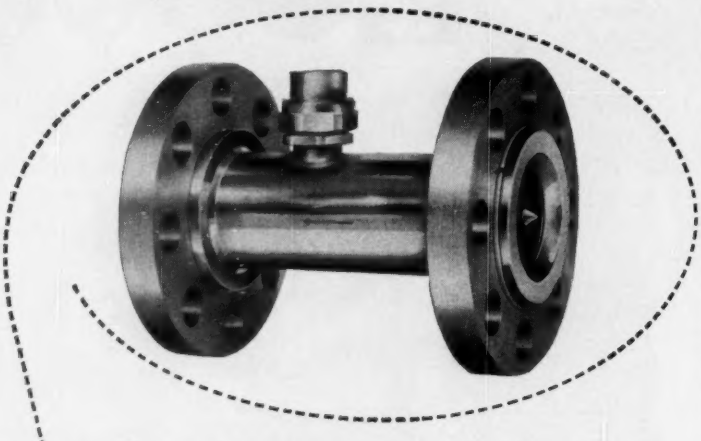
HELICOID GAGES

Helicoid Gage Division • American Chain & Cable Company, Inc.

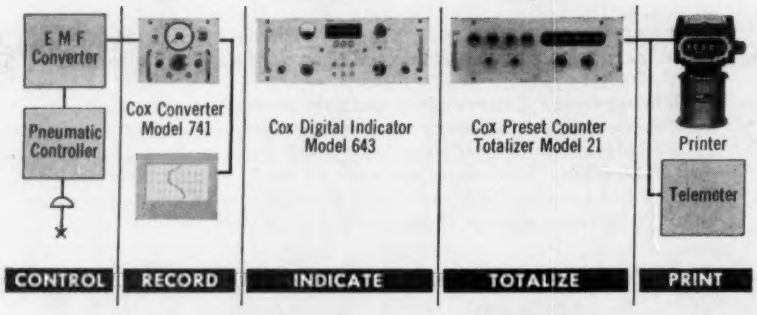
929-B Connecticut Ave., Bridgeport 2, Conn.

CIRCLE 120 ON READER-SERVICE CARD

Start Right!



with **COX Turbine Flowmeters**



The most important element in any flow measurement or control system is the *primary* transducer. Start with a good signal and the final readout or control will be good. And, as many users are finding, a good way to start is with Cox Turbine Flowmeters. Here's why—

Signal output versus flowrate is extremely stable and is *±1/4% or better of actual flowrate* with rangeability as high as 65:1. Besides, Cox turbine flowmeters are rugged . . . usable with most fluids at extremes of temperature and pressure . . . and *are easily disassembled for cleaning in a matter of seconds without affecting calibration.* To insure complete system accuracy, Cox also builds auxiliary readout and control equipment.

For more information write *Cox Instruments, George L. Nankervis Company, 15300 Fullerton Avenue, Detroit 27, Michigan.*

Write for Handbook on Cox Turbine Flow Measurement and Control Systems No. 3000.

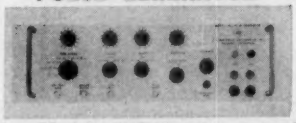
COX INSTRUMENTS

Division of **GEORGE L. NANKERVIS COMPANY**

Representatives in principal cities.

CIRCLE 121 ON READER-SERVICE CARD

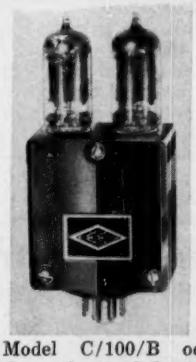
PULSE GENERATOR



New Model 131 Pulse Generator has 10-nanosec rise time and delivers 50-v pulse into 50 ohms.—*E-H Research Laboratories, Inc., 163 Adeline St., Oakland 6, Calif.*

CIRCLE 309 ON READER-SERVICE CARD

OPERATIONAL AMPLIFIER



New Model C/100/B octal-base plug-in Operational DC Amplifier for analog computer and instrument applications has gain of 30,000 dc open loop. Band width is over 400 kc with 0.6 μsec rise time as unity inverter. Output 3 ma over ±100-v dc; may be short-circuited without damage.—*Embree Electronics Corp., 993 Farmington Ave., West Hartford 7, Conn.*

CIRCLE 310 ON READER-SERVICE CARD

CRYSTAL MOUNTS

New line of Coaxial Crystal Mounts has four basic types which will hold the ceramic cartridge, small and large coaxial, and tri-polar types of crystals. They are equipped with a choice of N, BNC, TNC, C, or HN male or female input connectors and BNC, TNC, or Microdot output connectors. A total of 6,250 combinations of crystal mounts are available for immediate delivery from stock.—*Microlab, 570 West Mount Pleasant Ave., Livingston, N. J.*

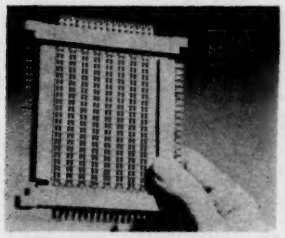
CIRCLE 311 ON READER-SERVICE CARD

STRAIN GAGE MONITOR

New Model 213 Digital Strain Monitor, a self-balancing instrument designed for continuous measurement of one-, two-, or four- active-arm strain gage elements, with individual resistance arm values of 50 to 1500 ohms, directly reads the output of resistance-type instruments such as strain gages, load cells, resistance thermometers, potentiometers, pressure cells, etc. Span settings permits sensitivity adjustment from ½ to 20 mv/v. Accuracy is 0.1%. Bulletin gives details.—*Technical Industries, affiliate of Packard Bell Electronics, 389 North Fair Oaks Ave., Pasadena, Calif.*

CIRCLE 312 ON READER-SERVICE CARD

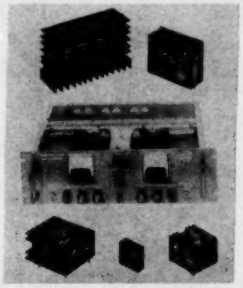
THIN FILM MEMORY



New 4" x 3¼" x 0.070" Type BIP-1000 Memory Planes store 20 words of 8 bits each or 160 bits, have cycle time of 0.2 μsec. Storage elements (planer Ni-Fe films vacuum deposited on glass substrate) change magnetic state by "spin rotation" in nano-seconds.—*Burroughs Corp., Electronic Tube Div., Box* 1226, *Plainfield, N. J.*

CIRCLE 313 ON READER-SERVICE CARD

SOLID-STATE POWER SUPPLIES



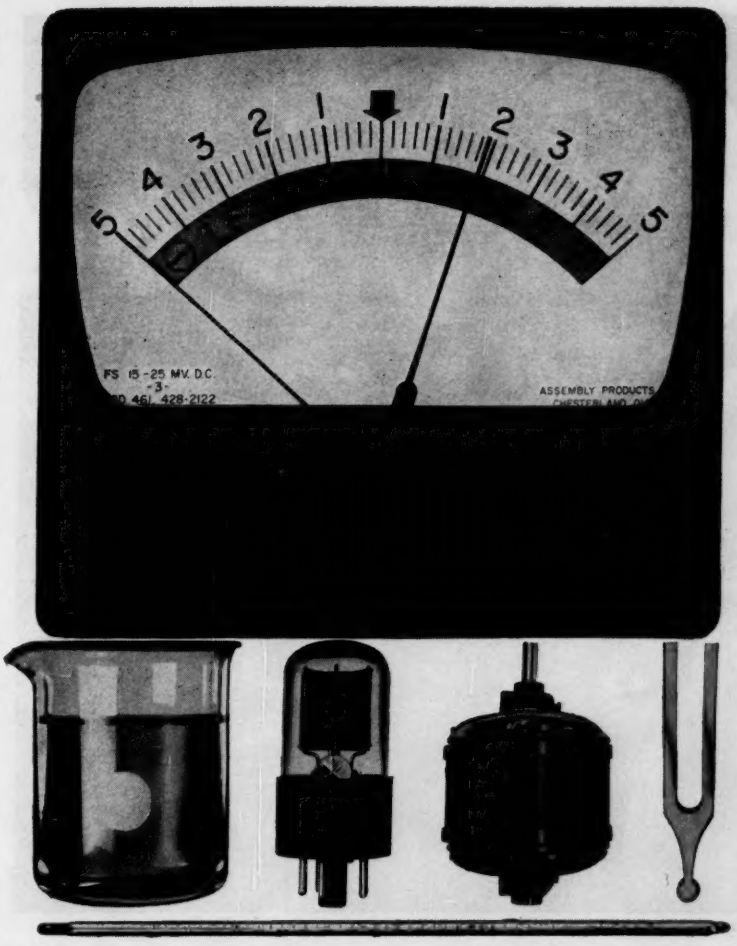
New solid-state, convection-cooled, 12-v Power Supplies operate in range of −20° to +65°C, feature less than 0.001-v rms ripple, have center tap to provide 33-v ac for auxiliary positive bias supply (except ZA-727). Model ZA-723 is 300-ma plug-in, Model ZA-724 is 3-amp chassis-mount, Model ZA-725 is 1-amp plug-in, Model ZA-727 is auxiliary +12-v, 100-ma, regulated bias supply.—*Engineered Electronics Co.,* 1441 *E. Chestnut Ave., Santa Ana, Calif.*

CIRCLE 314 ON READER-SERVICE CARD

VALVE ACTUATORS

Three new air-powered diaphragm operators for remote actuation of diaphragm valves (air-open air-close, air-open spring-close, and air-close spring-open) are built in four sizes for ½" to 2" valves. Operators actuate diaphragm valves at line pressures to 150 psi; optional positioner with indicator provides for throttling. —*Hills-McCanna Co.,* 4600 *W. Touhy Ave., Chicago* 46, *Ill.*

CIRCLE 315 ON READER-SERVICE CARD



WITH A. P. I. METER-RELAYS YOU CAN MONITOR AND CONTROL JUST ABOUT ANYTHING!

Handy gadget, the A.P.I. meter-relay. You can use it to indicate, monitor, and control practically any electrically transduceable variable. Things like moisture content, pH, motor load, radiation level, temperature, speed, light, sound. And, because it's so highly sensitive (0-5 microamps or millivolts is the minimum range), you can pipe-in thermocouple, strain gauge and other low-level signals directly, without amplification.

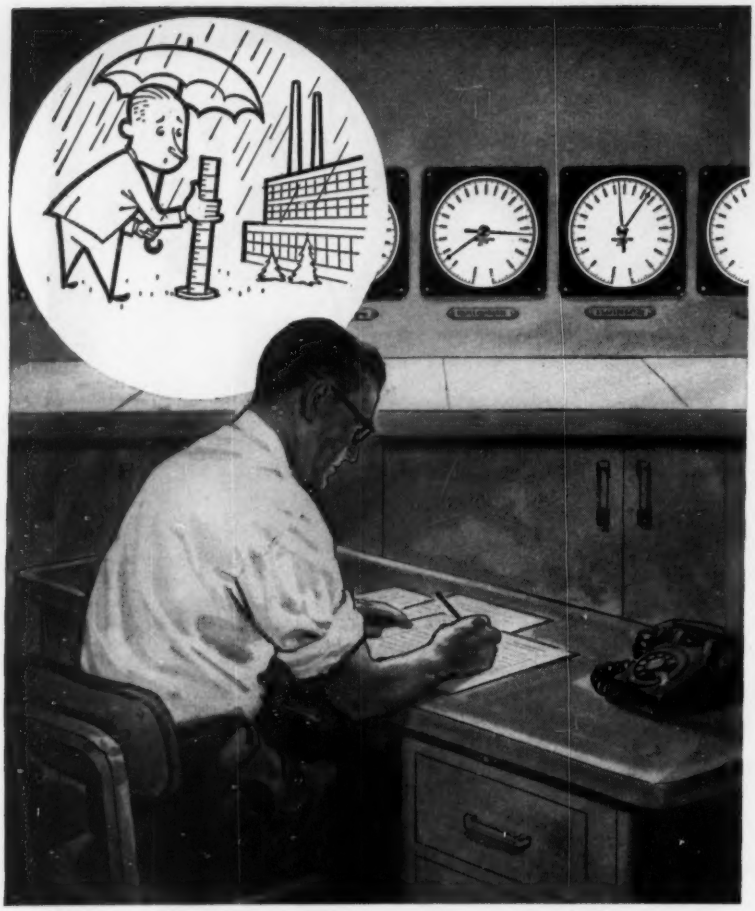
It's a highly reliable device, too. You can reasonably expect to get at least 10,000,000 perfect make-break operations. You'll probably get twice that many. We have.

You can spec A.P.I. meter-relays in any range you want, from the minimums mentioned up to 0-50 amps or 0-500 volts, AC or DC. We can calibrate scales in any units you require. Control set-points can be either single (high or low) or double (both high and low). Catalog 4J will give you much useful and interesting information about meter-relays. It will also give you detailed, explicit specs and prices. Yours for the asking, of course.

ap **ASSEMBLY PRODUCTS INC.**
CHESTERLAND 10, OHIO

SA 2396

CIRCLE 122 ON READER-SERVICE CARD



Take the legwork out of liquid measurement

Here's practical liquid measuring—the modern way... without roaming all over the lot! Liquidometer Gauges let you inventory distantly stored liquids at a glance.

Completely automatic Liquidometer Gauges can be located as far as 250 feet from tanks. Think what this centralized system can mean in man-hours saved—let alone the additional safety of personnel who no longer have to trudge to, or tamper with, hard-to-get-at tanks.

Simple to install, and requiring no maintenance, Liquidometer Gauges measure virtually all liquids conveniently, continuously, and correctly. There's a type available for practically every liquid measuring application.

For complete details, write

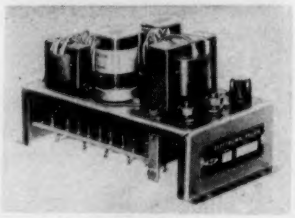
LIQUIDOMETER INSTRUMENTS

THE LIQUIDOMETER CORP.

Dept. E, LONG ISLAND CITY 1, NEW YORK

CIRCLE 123 ON READER-SERVICE CARD

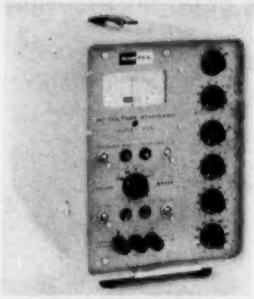
SOLID-STATE RELAY



New Model 120 all-transistor Relay has 25-v, 150-ma d-c output, accepts 60-cps a-c, or d-c inputs. Turn-on point adjustable from 3 to 150 volts input, independently controlled turn-off point range from 50-100% of turn-on voltage.—*K-F Products, Inc., 3100 E. 43rd Ave., Denver 16, Col.*

CIRCLE 316 ON READER-SERVICE CARD

VOLTAGE STANDARD



New Model 302 DC Voltage Standard and Null Voltmeter has short-term stability better than 25 ppm, stability over 30-day period better than 50 ppm. Voltage settings made in 1-mv increments; up to 20 Ma of current available at any output from 1.000 to 502.110v.—*Kintel Div., Cohu Electronics, Inc., 5725 Kearny Villa Rd., Box 623, San Diego 12, Calif.*

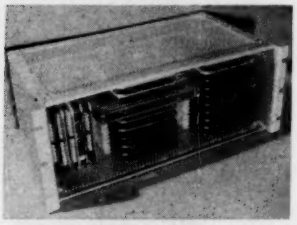
CIRCLE 317 ON READER-SERVICE CARD

SOLENOID VALVE

New Solenoid Valve for control of radioactive corrosive chemical solutions handles solutions in radiation field as high as 25 million rads. Available in standard ¼" pipe sizes (up to ¾" in specials) for normally closed and normally open applications in all normal a-c and d-c voltages.—*Valcor Engrg. Corp., 365 Carnegie Ave., Kenilworth, N. J.*

CIRCLE 318 ON READER-SERVICE CARD

INSTRUCTION MEMORY



New high-speed Biax magnetic core instruction memories operate at 1 Mc, with access time of 0.4 μsec using non-destructive readout Biax memory elements. No rewrite circuitry needed; standard input from punched paper tape, loading equipment detachable.—*Computer Products Operations, Aeronutronic Div., Ford Motor Co., Ford Rd., Newport Beach, Calif.*

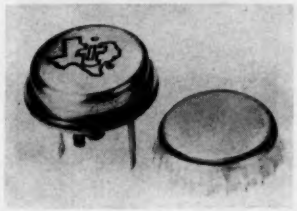
CIRCLE 319 ON READER-SERVICE CARD

SWITCHBOARD METERS

New Type AB-30 (a-c) and DB-30 (d-c) switchboard instruments feature 1% accuracy range, 10 to 20% savings in costs. Include voltmeters, ammeters, frequency meters, wattmeters, varmeters, power factor meters, synchroscopes.—*General Electric, Schenectady 5, N. Y.*

CIRCLE 320 ON READER-SERVICE CARD

TRANSISTORS



New TO-36 "pancake" series of germanium power Transistors features 150-w dissipation, lowest profile in TO-36 case, and 0.5°C/W max thermal resistance. Features: 100°C junction temp, guaranteed h_{FE} ranges from 20 to 70, rugged internal and external structure.—*Texas Instruments Inc., Box 5012, Dallas 22, Tex.*

CIRCLE 321 ON READER-SERVICE CARD

GYROTORQUER SUPPLY

Programmable constant current source for measurement of precision gyros or semiconductors designated CS-117 has a range of 0.1 μa to 150 ma from 0 ±100 v dc. Current is set to six places by decade divider, and may be programmed or modulated by remote signal. Line and load regulation are better than 0.0025% with stability assured by chopper feedback system.—*North Hills Electric Co., 402 Sagamore Ave., Mineola, N. Y.*

CIRCLE 322 ON READER-SERVICE CARD

THE SPARE PARTS PROBLEM

The Electronics Business may not be the most tranquil enterprise for anyone to get into — either as a buyer or seller — as evidenced by one of the problems currently plaguing both component makers and their customers. In a nutshell, the trouble is "equivalent" parts, made by a low bidder, failing to behave as the originals did. The explanation, while not as simple as this, seems to boil down to the fact that specs and descriptive data alone aren't enough for anyone to duplicate the *performance* of somebody else's original part. It could be a matter of the inability of the blueprint and the mimeograph machine to be a satisfactory substitute for the original manufacturer's experience, engineering skill, assembly methods and quality control.

No one can argue the merits of saving money, and a good part at the lowest possible cost is a commendable achievement. But when "low quote" means failure of critical equipment and personal hazard, there's not much to be said for economy. On the other hand, if the low man *does* get all the information he needs to build an exact replacement of the original part (assuming he can build it), he is automatically getting the benefit of a great deal of work done and paid for by the original manufacturer. The polite term is usually "proprietary data." Understandably, this arouses the "unfair competition" ogre.

We don't like to give away proprietary information any more than the next person. Neither do we like to see unreliable components endangering life and limb. We think part of the answer* may be to give the second man the same *problem* you gave the original supplier—not the blueprinted solution to imitate. Then test his result as carefully as you did the original successful one. This way, the odds are strongly in favor of your getting something that *will* work —and perhaps work even better.

What do you think the answer is?

*E. W. Schrader, Western Editor of DESIGN NEWS, made some good observations on this whole subject; see pp. 6-7, Jan. 16 issue.

SIGMA

SIGMA INSTRUMENTS, INC.
75 Pearl St., So. Braintree 85, Mass.

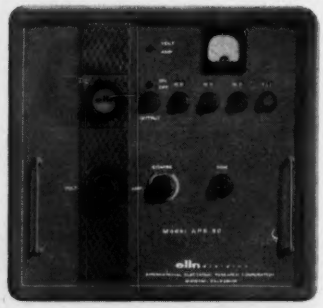
CIRCLE 124 ON READER-SERVICE CARD

elin AC calibration instruments offer 3 versatile concepts to meet most applications!

ELIN Model VC-555 ($895.00)

VC-555, a flexible unit, rugged, portable, for production line calibration of new-type differential voltmeters.

APS-50, used with Primary Transfer Standards requiring continuously variable frequency and voltage outputs at 50 VA.



ELIN Model APS-50 ($2,975.00)

ELIN **Model DK-102** ($395.00 each) Precision Power Oscillators in modular systems function independently. Each unit gives single frequency and voltage with precise, highly stable outputs. Shown in digital voltmeter calibration work at Hughes Aircraft Corp., Culver City, California. (Hughes Photo). **Write for catalog, today!**

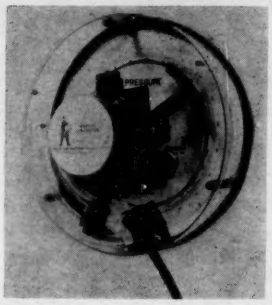
elin DIVISION

INTERNATIONAL ELECTRONIC RESEARCH CORPORATION

135 West Magnolia Boulevard, Burbank, California • Victoria 9-2481

CIRCLE 125 ON READER-SERVICE CARD

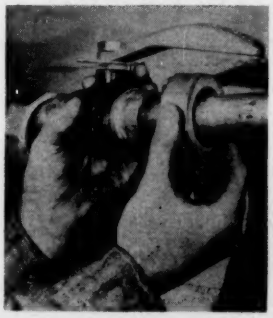
DIGITAL CONVERTER



New Digital Converter for Pointer Instruments consists of scanner unit (shown) which attaches to pointer instrument and electronic unit which houses circuitry and digital display. Scanner translates angular position of pointer into pulse time interval with accuracy of 0.1 ±1 count, resolution of 1 part in 1000; output display is Nixie-type tube with three digits.—*MacLeod Instrument Corp., 4250 N. W. 10 Ave., Fort Lauderdale, Fla.*

CIRCLE 323 ON READER-SERVICE CARD

BALL VALVE



New Petro Ball Valve features improved sealing, 1-piece forging, and built-in union ends. Max pressure rating for all sizes of valves with buna-N and neoprene seats is 300 psi; Teflon seats are rated to 600 psi for 1" through 2" valves, to 1,000 psi for ¼" through ¾".—*Clayton Mark & Co., Forged Steel Products Div., 1900 Dempster St., Evanston, Ill.*

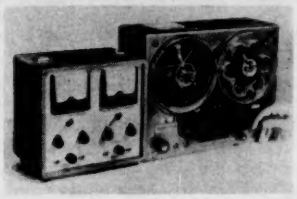
CIRCLE 324 ON READER-SERVICE CARD

ATOMIC ABSORPTION SPECTROMETER

New double-beam atomic Absorption Spectrometer with automatic readout system complete for use in ultraviolet, visible and near infrared regions of 2000 to 7700Å spectrum, is "first to be announced by a U.S. commercial instrument manufacturer." Double-beam system easily attains high precision for trace metal determination since source variations are cancelled.—*Perkin-Elmer Corp., Norwalk, Conn.*

CIRCLE 325 ON READER-SERVICE CARD

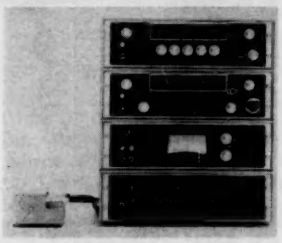
RECORD/REPRODUCE SYSTEM



New Model 102A portable 2-channel Record/Reproduce System with tape transport uses pulsed FM principle and transistorized circuitry, achieves 0.2% precision in recording and reproduction of analog data from 0-400 cycles. Features: 3 tape speeds, wide dynamic range, independent record and reproduce channels, low noise and low crosstalk.—*Mnemotron Corp., 3 N. Main St., Spring Valley, N. Y.*

CIRCLE 326 ON READER-SERVICE CARD

NUCLEAR INSTRUMENTS



Four new high-performance radioactivity-measuring chassis instruments can be purchased separately or integrated in one unit, Logic 801 (shown): (1) Preamplifier amplifies pulses from detectors; (2) High Voltage Supply provides stable polarizing potential for radiation detectors; (3) Scaler counts pulses received from detector; (4) Timer records length of time counting, or stops counting at preset time.—*Nuclear-Chicago Corp., 359 E. Howard Ave. at Nuclear Dr., Des Plaines, Ill.*

CIRCLE 327 ON READER-SERVICE CARD

PRESSURE TRANSDUCER

A current-feedback, torque-balance pressure transducer with low drift qualities, the A-2 is widely used in electronic pressure-control systems for blowdown tunnels and aircraft engine altitude test facilities where high absolute accuracies are required. Because of its speed or response (3 db at 40 cps), it is used also extensively in single-or multiple-pressure readout systems with suitable digitizing and printing equipment. Standard output ranges are 3 to 28 v and 0 to 25 v. Resolution sensitivity is 0.001% of full scale and calibration accuracy 0.1% of full range. Linearity is 0.05% full scale.—*Hagan Chemicals and Controls, Inc., Controls Div., Box 1346, Pittsburgh 30, Pa.*

CIRCLE 328 ON READER-SERVICE CARD

EXTENDING MAN'S SENSES IN HIS ENVIRONMENT AND BEYOND!

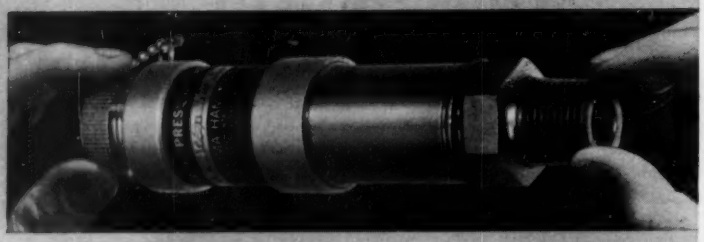
TOUCH

With our dynamic progress in the technological sciences . . . man's sensorial abilities have been relegated to a point of lesser importance. Instrumentation — many times more perceptive than our sense of "touch" — is paramount! Such instrumentation is evident in the Proximity Scorer — engineered and produced by Franklin Systems, Inc. The Scorer records near-misses of up to 30 feet of a towed target or drone. A projectile is tagged with a speck of radioactive material and when passing within a radius of the target, a hit is scored via a counter contained in the target.

FRANKLIN SYSTEMS
INCORPORATED
2734 HILLSBORO ROAD • WEST PALM BEACH, FLORIDA • TE 3-4602

CIRCLE 126 ON READER-SERVICE CARD

NEW GP PRESSURE CELL BY BLH ...NEVER BEFORE SUCH ACCURACY AND STABILITY AT SUCH LOW COST



At last . . . a simplified, rugged pressure transducer for measuring fluid pressures from 100 to 10,000 psi . . . with a calibration accuracy of 0.15%.

Feature by feature, the new GP Pressure Cell was engineered to outperform and outlast any pressure measuring device on the market. It is completely calibrated and stabilized . . . ready for immediate installation. There are no moving parts to cause friction losses. Requires less warmup time. Has extremely low sensitivity to shock and vibration.

Recalibration in the field is easy and fast. No bobbin type resistors to wind. All external compensating resistors are readily accessible.

SR-4® Foil Strain Gages bonded intimately to the outside surface of a precisely machined stainless steel tube sensing element assure highest possible stability and accuracy. Output sensitivity is a high 3mv/v, with no sacrifice in safety factors or overload performance.

All stainless steel construction provides positive protection against undesirable environmental conditions.

Temperature compensated over a range of 0°F to +150°F. Precise electrical shunt calibration over the full range. Calibration certificate, provided with each pressure cell, gives complete data on linearity, hysteresis and repeatability. Choice of electrical and pressure connections.

Write for new data sheet telling how you can apply this advanced design pressure transducer in industry-wide applications.

BALDWIN • LIMA • HAMILTON
Electronics & Instrumentation Division
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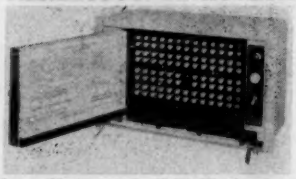
FIRST in force measurement

SR-4® Strain Gages • Transducers • Temperature Sensors • Systems

CIRCLE 127 ON READER-SERVICE CARD

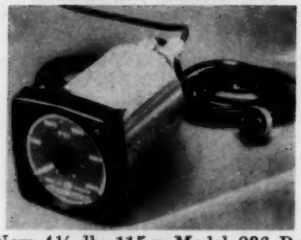
THERMOCOUPLE HOTBOX



New Universal TC Hotbox joins thermocouple wire directly to copper deep within its heat sink; uses ice bath principle, except that junction temps are accurately controlled at 150°F. Tapered plastic sleeves wedge each thermocouple wire (to 51 pairs) into separate heat-sink socket.—*Research, Inc., Box* 6164, *Minneapolis* 24, *Minn.*

CIRCLE 329 ON READER-SERVICE CARD

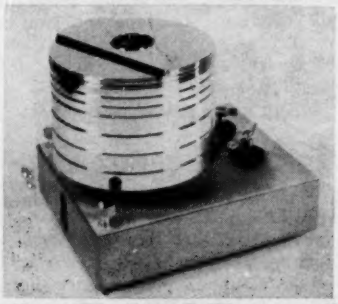
PRESSURE INDICATOR



New 4½ lb, 115-v Model 236 Pressure Indicator remotely indicates gas pressure, fluid pressure, thrust, and torque, operates in ranges of 0-50 to 10,000 psi. Consists of voltage-regulated 60-cycle power supply for excitation of strain gage bridge, amplifier power supply, and transistor amplifier to increase voltage level of bridge output to d-c meter movement. Data Sheet P-60236.—*Taber Instrument Corp.,* 107 *Goundry St., North Tonawanda, N. Y.*

CIRCLE 330 ON READER-SERVICE CARD

DEAD WEIGHT TESTER



New "Floating Ball" pneumatic Dead Weight Tester Model 750-A is primary pressure standard incorporating friction-free spherical piston. Application of calibrated weights is only manipulation required during operation. Inherent self-regulation quickly produces sustained output pressure proportional to weights applied. Resolution, repeatability, and hysteresis better than 0.005% of output; accuracy, 0.05% of output. Pressure ranges to 61 psi.—*R. J. Karr Co.,* 1605 16 *St., Wyandotte, Mich.*

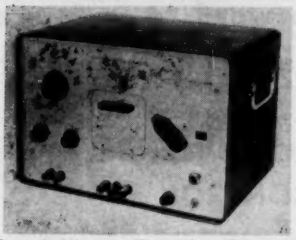
CIRCLE 331 ON READER-SERVICE CARD

SINGLE DISC MEMORY

New 31" Single Disc Telex 31B has 2 recording surfaces, 8 movable data heads for total memory capacity of nearly 10 million bits with 400,000 bits available on fast access basis comparable to magnetic drum performance. Provides over 9 million bits of random access storage capacity with average access time of 147 msec. —*Telex, Inc., Data Systems Div.*, 2615 *1st Natl. Bank Bldg., Minneapolis* 2, *Minn.*

CIRCLE 332 ON READER-SERVICE CARD

FUNCTION GENERATOR



New Arbitrary Function Generator, in addition to yielding low frequency sine and triangle waveforms, reproduces arbitrary waveforms to customer specs. Frequency range of 0.001 to 10 cps in four ranges; accuracy of ±3% of set frequency; output of 20 v max peak to peak, adjustable.—*Tensor Electric Development Co., Inc.*, 1873 *Eastern Parkway, Brooklyn* 33, *N. Y.*

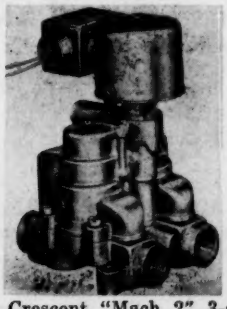
CIRCLE 333 ON READER-SERVICE CARD

MAGNETIC AMPLIFIERS

New Mega-Power 1310 Series Magnetic Amplifiers in 7 sizes from 75-400 hp are for applications requiring high-capacity controlled d-c power for variable speed d-c motor drives (in plating, electrochemical processes, accelerator magnets, etc.). Have advantages over motor-generator power supplies. Bulletin 1316-3.—*Vickers Inc., Electric Products Div.*, 1815 *Locust St., St. Louis* 3, *Mo.*

CIRCLE 334 ON READER-SERVICE CARD

AIR VALVES



New Crescent "Mach 2" 3-and 4-way air valves rated for 1000 cycles per minute continuous duty feature 3/32" solenoid plunger stroke (reducing coil heating) and reduced friction in pilot and main valve members. Rated at 150 psi air, valves are available in ¼" to ¾" pipe sizes.—*Barksdale Valves*, 5125 *Alcoa Ave., Los Angeles* 58, *Calif.*

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Your biggest value in

DIGITAL DATA LOGGING

Data-Master® modular design makes data logging easy, economical, and outstandingly versatile

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Only Data-Master gives you this outstanding freedom of choice. For example, look at these standard optional features:

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  - *Common limit*
  - *Multiple limit systems*
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  - *Alarm scanning only*
- *Read-out options*
  - *Typewriter*
  - *Tape punch*
  - *Card punch provision*
  - *Printer*
  - *Strip chart record*
  - *Combinations of above*

. . . And many others

Logs practically any variable over any range, for example: temperature, pressure, flow, liquid level, pH, humidity, etc.

Automatically logs data from up to hundreds of points, hundreds of instrument readings.

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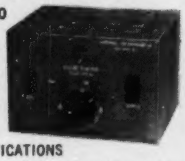
NEW!

ELECTRONIC TEST EQUIPMENT

PHASE SHIFTER

Models PS60 & PS400



For measurement and comparison of phase angles or as a secondary phase standard

SPECIFICATIONS

RANGE..... 0-360° (continuously variable)
ACCURACY..... ±1 degree
(Higher accuracies available)
FREQUENCY..... 60 CPS for PS 60
400 CPS for PS 400
(other frequencies available)

FREQUENCY STANDARD

A SELF-CONTAINED FORK STABILIZED FREQUENCY SOURCE

- Accurate
- Stable
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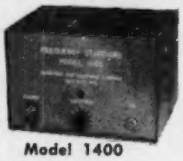
- Variable output voltage
- Compact



Model 1400

SPECIFICATIONS

ACCURACY..... Available to .005%
DISTORTION..... Less Than 1%
FREQUENCY..... 400 CPS or 1000 CPS
(Other Freq. Avail.)
Dimension..... 6x9x6 inches
Power Supply..... 115 volts, 60 CPS

OTHER MODELS AVAILABLE

MODEL 608 LOW FREQUENCY STANDARD — DESCRIPTION: Utilizes scaling circuits to provide tuning fork accuracies at frequencies below the range of precision tuning forks.

AUTOMATIC HI-POT TESTER

Model A

FAST, ACCURATE, DIELECTRIC TESTING FOR MULTI-CONDUCTOR DEVICES

DESCRIPTION: The function of this instrument is to apply in programmed sequence a known voltage between the various conductors under test for a specific period of time and to indicate breakdowns when and where they occur.

SPECIFICATIONS

TEST VOLTAGE..... 0-2000 Volts RMS
TEST TIME..... 2-120 seconds
NUMBER OF TEST TERMINALS..... 11

NULL DETECTOR

Model 608

A sensitive battery operated null detector ideal for ahering bridges or other applications where complete isolation from power lines is desirable.

• Long Battery Life • High Harmonic Rejection • Shielded against external fields

SENSITIVITY: 1 microvolt for 1% deflection

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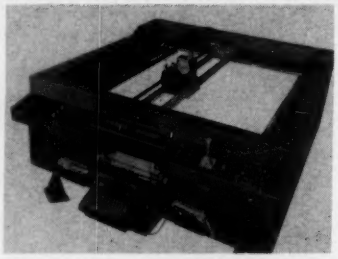
CIRCLE 145 ON READER-SERVICE CARD

TAPE PLOTTING SYSTEM

New digital Magnetic-tape System, Type 575, which permits plotting of digital computer results in continuous-curve form on an X-Y recorder, includes a digital tape transport, a digital magnetic tape translator, tape control unit, record-play amplifiers, and an Tutograf X-Y recorder. Computer tape speed is 75 o r112.5"/sec. The tapes are played back on a slow-speed 3"/sec tape transport for recording on conventional X-Y charts. Few controls are needed as complicated tape editing and digital "computing" hardware have been replaced by decks of IBM cards. Accuracy of the dig/an conversion is better than ± 0.1% of full scale. The translator is completely transistorized and features illuminated visual display, automatic parity checking and automatic search mode.—*F. L. Moseley Co., 409 North Fair Oaks Ave., Pasadena, Calif.*

CIRCLE 336 ON READER-SERVICE CARD

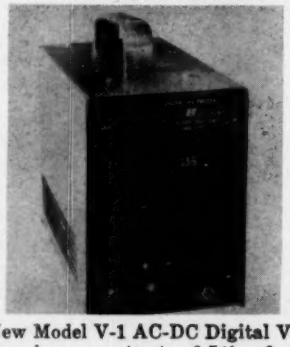
48" x 48" X-Y PLOTTER



New automatic Digital X-Y Plotter assures accuracy of ±00.001" on 48" x 48" working surface. Operates on digital measurement basis instead of percentage; eliminates warm-up time and possibility of drift. Slewing speeds are 0.004", 0.08", 0.8", and 4" per second or faster.—*Gerber Scientific Instrument Co., 89 Spruce St., Hartford, Conn.*

CIRCLE 337 ON READER-SERVICE CARD

DIGITAL VOLTMETER



New Model V-1 AC-DC Digital Voltmeter is accurate to 0.5% of full scale for d-c voltage measurement, 1.0% for current measurement. Also, new digital DC Ammeter and Multimeter incorporating AC-DC Ammeter combine low cost with ruggedness and precision.—*Electro-Logic Corp., 515 Boccoccio Ave., Venice, Calif.*

CIRCLE 338 ON READER-SERVICE CARD

READERS & ADVERTISERS

have a lot to look forward to in future issues of

INSTRUMENTS and CONTROL SYSTEMS

Each issue will highlight one of the instrument-control topics below—

Temperature Measurement and Control

Telemetering

Recording

System and Data Instrumentation

Numerical Control

Process Instrumentation (Valves)

Analytical Instrumentation and Stream Control

Current and Voltage Control

READERS will find each issue almost a text in itself.

ADVERTISERS will share in the resultant reader enthusiasm.

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MANUFACTURERS . . .

Don't forget to submit your free listings for ICS 1962 Buyers' Guide. Publication in October 1961. Ad closing date—August 31.

VOLTAGE DIVIDER

New Model VDR-105 secondary standard Voltage Divider (inexpensive version of VDR-106) is used for: calibrating resistance-ratio sets, measuring relative voltage current or resistance over wide ranges, standardizing lab instruments. Unit is 5-decade Kelvin-Varley divider, with accuracy, resolution and long-term stability rated at 0.001% (vs 0.0001% of 6-decade VDR-106).—*Julie Research Laboratories, Inc., 603 W. 130 St., New York 27, N. Y.*

CIRCLE 339 ON READER-SERVICE CARD

COLD LIGHT SOURCE

New Aristo Mic-O-Lite II featuring four rings of cold shadowless light in a doughnut-type reflector, 6" in dia, which provides a 2¼-inch aperture in its center, is an ideal source for precision inspection under magnification.—*Aristo Grid Lamp Products Inc., 65 Harbor Rd., Port Washington No., L. I., N. Y.*

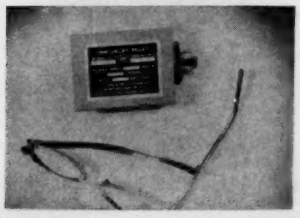
CIRCLE 340 ON READER-SERVICE CARD

DIAPHRAGM RELIEF VALVE

New Series 1000 Diaphram Relief Valve, which provides vapor tight seal to prevent leakage and eliminate waste, has spring and guides isolated from process fluid to avoid corrosion. Especially suited for nitrogen, light gas service, and water treatment. Catalog FE-138.—*Farris Engineering Corp., 610 Commercial Ave., Palisades Park, N. J.*

CIRCLE 341 ON READER-SERVICE CARD

TIME DELAY RELAY



New Model 591 plug-in, electronic time delay (intervals 0.003 to 300 sec) with instant recycle is available in single-and double-pole double-throw models. Uses cold-cathode tube. Time delays can be fixed or adjustable.—*G. C. Wilson & Co., Box 5525, Huntington, W. Va.*

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The Hungarian instrument industry, represented by METRIMPEX, Budapest 62, POB 202, presents its newest products together with scores of manufacturers from most other important industrial countries at the

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Tubing Bundles

Polyethylene Tubes enclosed in Virgin Plastic Sheath

Tough plastic outer sheath with excellent chemical atmospheric resistance. Inside tubes are polyethylene. Lengths to your requirements.

Send specifications for quotation.

STOCK POLYETHYLENE TUBING
¼" O.D. x .040" wall and ⅜" O.D. x .062" wall, in standard colors.

PLASTIC COATED METAL TUBING
Standards and specials to order.

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"INSTRUPACK" SPECIFICATIONS

¼" or ⅜" Polyethylene Tubing.

Vinyl or Polyethylene Sheath .045"or .062" thickness or as required.

Color Coded or Black Numbered Tubes.

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Mylar Wrap between Tubes and Sheath.

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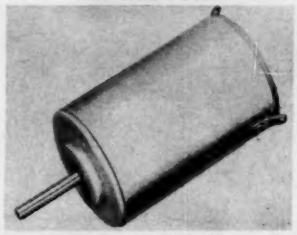
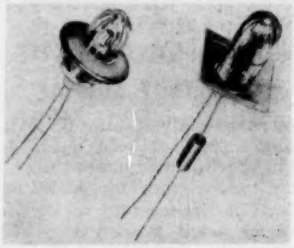
BATTERY-OPERATED DC MOTOR



New 1"-dia Type HYQM d-c Motor for battery-operated dictating machines, tape recorders, etc., features high-efficiency low current drain, square brushes with pigtail connections, self-aligning sleeve bearings or ball bearings. Governor optional. Specs: 4.5-30 v dc, 1500-5000 rpm (governed), 0-0.20 oz-in torque.—*Barber-Colman Co., Motors and Components Div., Rock St., Rockford, Ill.*

CIRCLE 343 ON READER-SERVICE CARD

INDICATOR ASSEMBLIES



New "Econoglo" Neon Glow Indicator Assemblies in two styles (with Tinnerman nut or snap-in plug) mount from front of panel, available with built-in current-limiting resistors. Plain, fluted, or flatcap lens.—*Drake Mfg. Co.*, 4626 *N. Olcott Ave., Chicago* 31, *Ill.*

CIRCLE 344 ON READER-SERVICE CARD

WATER ANALYZER-RECORDER

New Chemonitor duplicates principles of colorimetric analysis, determines and records continuous on-stream analysis of water. Recorder may operate as upper-limit switch. In 0-300 parts per billion silica range, unit detects concentrations of 5 ppb ±2.—*Water Chemicals Div., Hagan Chemicals & Controls, Inc., Hagan Center, Pittsburgh* 30, *Pa.*

CIRCLE 345 ON READER-SERVICE CARD

METRAPONT-BRIDGE

New Metrapont-Bridge uses Wheatstone bridge circuit to measure dc and is connected to transistor amplifier with phase comparison for ac measurements. Transistor oscillator feeds 800 cps to bridge. Features dc resistance measurements of 0.05 megohms; capacity measurements of 5 PF to 50 microfarads.—*Physics Research Labs., Box 555, Hempstead, N. Y.*

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PILOT-POSITIONER

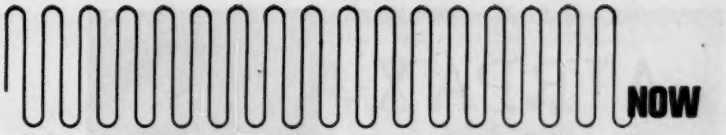
New Pilot-Positioner combines a pneumatic controller with a separate valve-mounted positioner by employing mechanical feedback from the valve stem through a lever system, in place of pneumatic feedback from a bellows assembly, as used in most controllers.—*U.S. Gauge, Div. of American Machine & Metals, Inc., Sellersville, Penna.*

CIRCLE 347 ON READER-SERVICE CARD

DIGITAL SET-POINT CONTROLLER

New Model JY Digital Set Point Controllers in 1-3 range models for temp or mv control have 3-digit, 1000-part dial, allowing control point increments as small as ½°. Calibration not affected by leadwire length; continuous electric cold junction compensation provided. Bulletin JY.—*West Instrument Corp., 4363 W. Montrose Ave., Chicago 41, Ill.*

CIRCLE 348 ON READER-SERVICE CARD



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make calculations directly in solving electroplating problems

No longer need you rely on empirical methods made necessary by previous types of current density cells. With this new Linear Electroplating (Cell) Analyzer, total polarization can be calculated directly. Developed at the Polytechnic Institute of Brooklyn, the Analyzer cell was specifically designed to give linear distribution of current density along the electrode. Thus, calculations can be made from simple measurements. The unit has extensive laboratory and field applications... is extremely useful in the control, development and study of plating solutions.

Fabricated of Plexiglass (II-A) to fine tolerances. The two sides holding the electrodes are opaque, the other two are clear Plexiglass to permit unobstructed observation.

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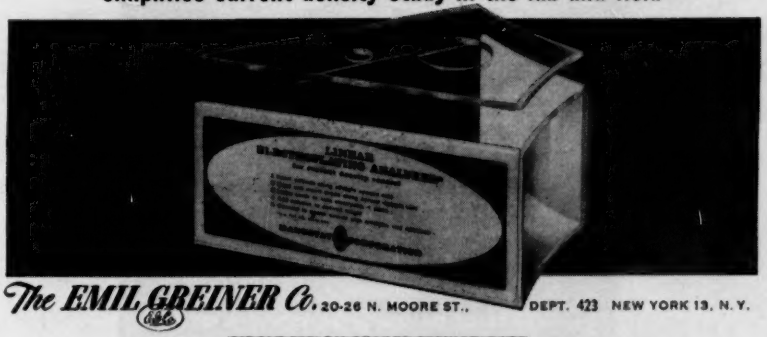
For reference, see J. ELECTROCHEM. SOC. 103 p. 549 (1956). Reprints on request.

New MANOSTAT Linear Electroplating (CELL) Analyzer simplifies current density study in the lab and field



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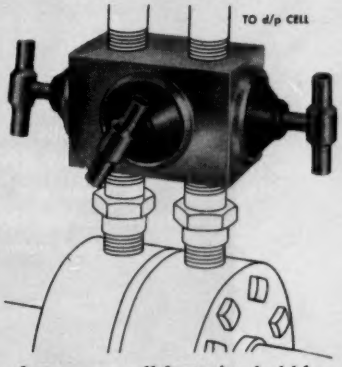
LOW COST VALVE MANIFOLDS ELIMINATE BY-PASS VALVES, FITTINGS, PIPING!



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Low cost "DEMI G" valves, in ⅛" to ½" N.P.T. sizes, provide positive control in minimum space. Many actuating devices. Wide selection of construction materials.

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AIRPAX and TELEMETRY

The Airpax all solid state Multichannel Frequency Discriminator uses a single front panel switch to select each of the 23 IRIG telemetry channels. The input comb filter extracts the required single channel frequency from the composite telemetry signal.

The meter displays an analog presentation of percent deviation from channel center frequency. Terminals are provided for a 1 megohm recorder load. Meter accuracy permits using the unit as a standard for calibrating voltage controlled oscillators and similar devices.

Input is 10 millivolts minimum, with a 60 DB dynamic range. Linearity is 0.25% or better of bandwidth and drift will not exceed 0.3% of bandwidth after initial warm-up.

Airpax also produces this unit without the comb filter as well as individual units for single channel monitoring. Single channel types have plug-in components permitting adaptation to any desired channel.

All units are priced considerably below comparable equipments. Size, weight, and power input are minimal.

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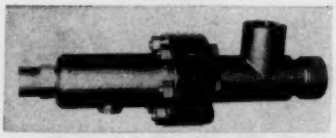
6842

VALVES



Six new valves for control, regulating and relief in industrial hydraulic systems are available for operating pressures up to 3000 psi. Applications include boiler testing.—*Besler Corp., 4053 Harlan St., Emeryville, Oakland 8, Calif.*

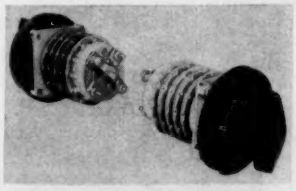
CIRCLE 349 ON READER-SERVICE CARD

CERAMIC POWER TRIODE

New D-1008 ceramic-metal Power Triod is water-cooled tube, featuring heavy wall copper anode and mesh type cathode. Tube rated at 60-kw full power input to 50 mc and reduced input to 110 Mc with max anode dissipation rated at 20 kw. As hard-tube radar modulator, D-1008 switches 220 amp at voltages up to 18 kv at rated cathode voltage.—*ITT Components Div., Electron Tube Div., Box 412, Clifton, N. J.*

CIRCLE 350 ON READER-SERVICE CARD

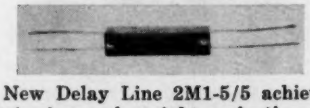
TYPE JM ROTARY SWITCH



New Type JM Rotary Switch with wholly enclosed contact mechanism controls up to 75 poles with single knob. Complies with BuShips drawings and Mil specs. Bulletin 22.—*Electro Switch Corp., King Ave., Weymouth (Boston 88), Mass.*

CIRCLE 351 ON READER-SERVICE CARD

DELAY LINE



New Delay Line 2M1-5/5 achieves 10:1 size and weight reduction by having 2 coils wound on each subminiature toroidal core and using temp-compensating ceramic disc capacitors. Attenuation of 1% (0.008 db), total delay 0.2 μsec, rise time 0.04 μsec, size 0.25" x 0.4" x 1.75".—*Valor Instruments, Inc., 13214 Crenshaw Blvd., Gardena, Calif.*

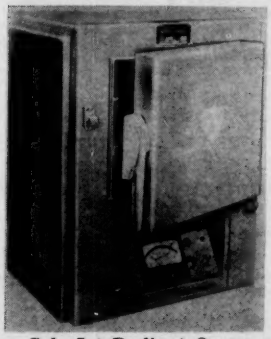
CIRCLE 352 ON READER-SERVICE CARD

TELEMETERING SWITCH

New miniature (8 oz, 1⅜" x 1¾" x 2½") Telemetering Switch provides up to 450 circuits for missiles and satellites. Low brush velocity extends operating life beyond 1000 hr. Drive motor drawing 60 ma at 28-v dc operates unit at standard speeds from 1-20 rps.—*Electro-Tec Corp.*, 10 *Romanelli Ave., South Hackensack, N. J.*

CIRCLE 353 ON READER-SERVICE CARD

RADIANT OVEN



New Sola-Jet Radiant Ovens maintain constant-controlled temperature by having heaters on all sides of chamber. Special "jack-in" heated aluminum shelves applying direct heat to work load are optional.—*Dept. 2, Temperature Engineering Corp., Riverton, N. J.*

CIRCLE 354 ON READER-SERVICE CARD

COOLER FOR IR DETECTORS

New Model FW-22 Cryogenic Cooler is designed for cooling dewar-type infrared detector cells with liquid nitrogen, liquid oxygen, or liquid air. Will operate continuously for 22 hours from filing. May be operated to obtain temperatures down to 63 degrees Kelvin with liquid nitrogen.—*Component Sales, ITT Laboratories, 3700 E. Pontiac St., Fort Wayne, Ind.*

CIRCLE 355 ON READER-SERVICE CARD

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positive temperature control

1. Pyrotroller—an electronic temperature controlling instrument.
2. Pyrotac—a safety excess temperature cut-out or alarm.

Dependable automatic control of temperatures in heat treating furnaces, ovens, plastic moulding, cooking vessels or for any constant temperature requirement. Operates to prevent overheating even with power failure.

The Alnor Flux Gate Sensing Coils

The simple, rugged circuitry in the Pyrotroller has a minimum of components that operate well below their rated capacities. The circuit is not critically tuned and there is no need for repeated adjustment, no shifting of the control point, no need for preselection of the one standard vacuum tube. Sapphire jewel bearings and the very high Alnor standard of precision construction makes the Pyrotroller extremely accurate particularly in the low temperature ranges.

The Alnor Pyrotroller is available in a wide range of temperatures, —100° F. through various maximum temperatures up to 3000° F. The minimum scale span is 400° F. and various ranges can be supplied to meet your particular installation. Write for complete information. Our engineering service is available on special requirements.

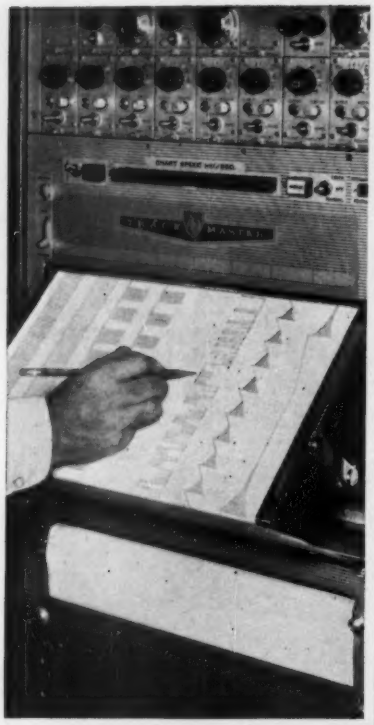
Alnor INSTRUMENTS

ALNOR INSTRUMENT CO.

Division of **Illinois Testing Laboratories, Inc.**

Room 518, 420 N. LaSalle St., Chicago 10, Illinois

CIRCLE 138 ON READER-SERVICE CARD



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Only the AO Tracemaster offers this convenient, tilt-out writing table. Smooth, positive linkage lets you tilt the exposed section of the chart out to a just-right 50° angle. An automatic braking device on the paper take-up mechanism maintains taut, wrinkle-free chart surface across the table.

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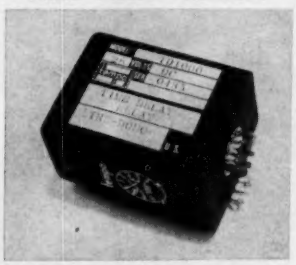
CIRCLE 139 ON READER-SERVICE CARD

COLLIMATOR

New portable Service Collimator checks long-range lenses and cameras in field despite weather conditions. Based on premise that collimator objective need not have focal length longer than lenses tested if it is corrected over considerable extra-paraxial field.—*Zoomar, Inc., Glen Cove, N. Y.*

CIRCLE 356 ON READER-SERVICE CARD

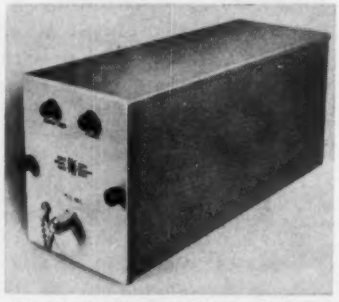
TIME DELAY RELAYS



New "Tru-Dodo" Time Delay Relays, with fixed time delay periods from 0.050 to 100 seconds, feature circuit design which provides true delay-on- drop-out logic, requires no power during timing cycle. With input power (28-v dc) removed, relay remains energized as solid state timing circuit starts timing cycle. At end of cycle, circuit fires and de-energizes control relay.—*Tempo Instrument Inc., Box 338, Hicksville, L. I., N. Y.*

CIRCLE 357 ON READER-SERVICE CARD

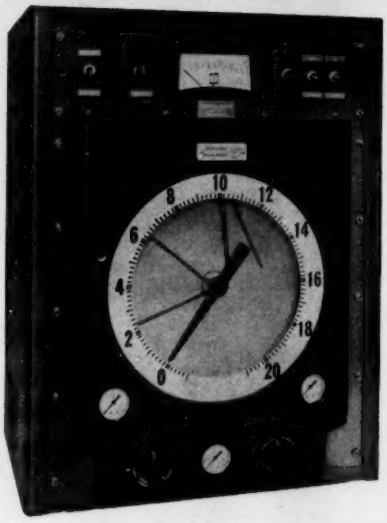
FREQUENCY STANDARD



New Model S-1159 Packaged Frequency Source has rated frequency of 1-Mc with stability (short term) of one part in one billion; combines precision crystal oscillator, proportionally controlled oven and transistorized circuitry. Measures 11.5" x 4.2" x 5"; weighs 5.5 lb. Characteristics: aging, 1 part in 10^8 per day; stabilization time required for aging rate, 72 hrs; warm-up time, 4 hr; frequency adjustment range, ±3 parts in 10^6; output, 50-mv sine wave.—*Reeves-Hoffman Div., Dynamics Corp. of America, Carlisle, Pa.*

CIRCLE 358 ON READER-SERVICE CARD

THERMA BRIDGE GAS ANALYZERS



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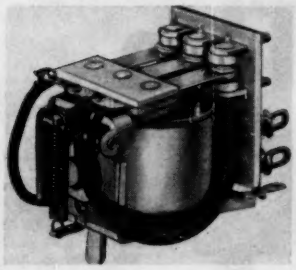
CIRCLE 140 ON READER-SERVICE CARD

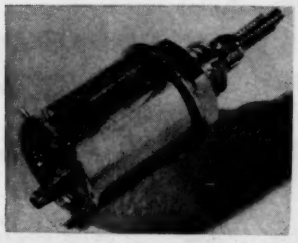
AC-DC RELAY



New Model 88 general purpose AC-DC Relay, interchangeable dimensionally with many similar-size relays, features: armature hinge-pin centerless ground of stainless with oversize precision reamed bearing surfaces, glass insulation, independently riveted coil terminals, molded nylon bobbins, built-in contact wipe, modular construction.—*Magnecraft Electric Co., 3350L West Grand Ave., Chicago 51, Ill.*

CIRCLE 469 ON READER-SERVICE CARD

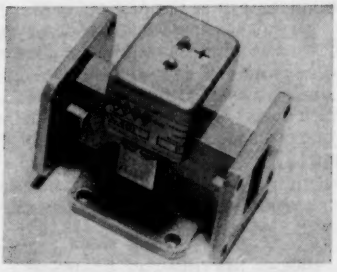
SHIELDED INDUCTORS



New series 900 slug-tuned shielded RF inductors for high quality applications, has range from 0.5 μh to 100 μh in 10 steps and is most useful over the 0.5 to 60 mc spectrum where the average Q is 70.—*North Hills Electronics, Inc., Glen Cove, L. I., N. Y.*

CIRCLE 470 ON READER-SERVICE CARD

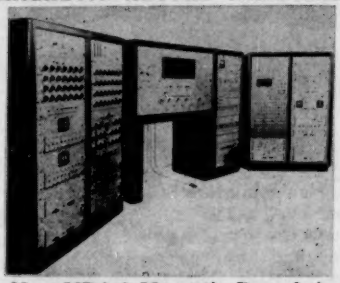
TEE CIRCULATOR SWITCH



New Tee Circulator Switch for use in frequency band 10.0-10.5 kmc provides isolation of 20 db between channels with insertion loss less than 0.4 db. Special tuning can peak isolation at any frequency in band. Switching requires 300 μsec with 2 v applied to actuating coil.—*Rantec Corp., Calabasas, Calif.*

CIRCLE 471 ON READER-SERVICE CARD

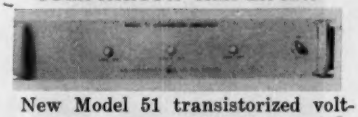
MAGNETIC RECORD ANALYZER



New MRA-2 Magnetic Record Analyzer provides complete flexibility, absolute and universal time corrections, playback in time or depth, system noise cancellation, optional functions packaged separately, drum and track geometry compatible with existing FM systems. Unit has 3-drums with 28 traces per drum, 4kc carrier frequency, deviation 1 to 7kc, and check trace of 100 cps from recorded tape.—*Electro-Tech Labs., Div. of Mandrel Industries, Inc., Box 13243, Houston 19, Texas.*

CIRCLE 359 ON READER-SERVICE CARD

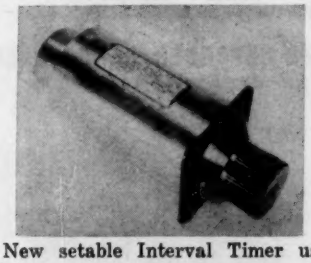
COMPARISON AMPLIFIER



New Model 51 transistorized voltage comparison Amplifier determines if an input voltage or series of input voltages is within preset limits by using colored bulbs and relays to operate warning and control devices within 90 msec. Sensitivity in excess of 500 μv and range of ±50 volts (up to 100 volts as long as limit-to-input differential does not exceed 25 volts).—*Non-Linear Systems, Inc., Del Mar, Calif.*

CIRCLE 360 ON READER-SERVICE CARD

INTERVAL TIMER



New setable Interval Timer uses miniature permanent magnet motor operating at stall as analog of mechanical spring for its time base. Motor drives safety and arming type escapement mechanism with accuracy of ±17% or 0.15 sec over all conditions of military environment. Manually set dial calibrated in 0.2-sec intervals from 0.2 to 28.0 sec. Any change in setting after starting causes timing cycle to abort.—*Globe Industries, Inc., 1784 Stanley Ave., Dayton 4, Ohio.*

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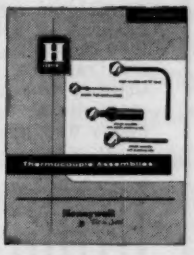
More than 100 complete T/C assemblies, available in a range wide enough to cover most applications in any industry, under any environmental conditions. Included are straight, angle, high-speed, high-temperature and spring-loaded assemblies. They are among many thousands of accessories—all available from a single dependable source—to help your instruments perform at their best.



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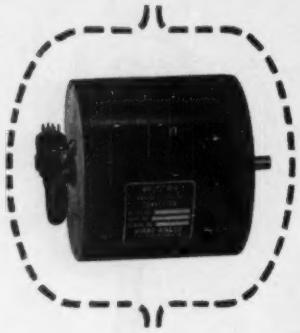
PHOTOTRON



FIRST IN NEW LINE OF ANALOG TO DIGITAL CONVERSION PRODUCTS FROM HYDRO-AIRE

This highly versatile basic transducer offers incremental conversion of shaft angle to digital measurement. Available in seven models, its maximum permissible speeds range from 15,000 rpm at 128 counts per revolution to 1,250 rpm at 2,048 counts, with sample rates ranging to 45,000 counts per second.

Applications for the Hydro-Aire Phototron include analog to digital shaft converters, precision analog servo with digital readout, data reduction equipment, tachometers, and precision measurement and control.

Detailed specifications are available on request. Related products soon to be available from Hydro-Aire, a member of the Crane Co. Systems and Controls Group, will include associated power supplies and binary and digital counters.

HYDRO-AIRE

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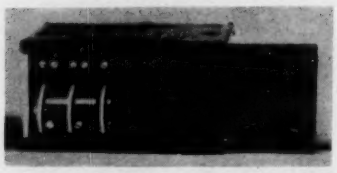
Solid-state devices include time delay devices, voltage regulators, power supplies, inverters.

CIRCLE 143 ON READER-SERVICE CARD

SEQUENCE TIMER



New miniature Sequence Timer (11 oz, 1½" x 2½" x 3") for space vehicle use provides switch closures during and after powered flight. Accuracy better than 3%; quick-set, accessible cams adjustable within 0.1% total period; adjustable time span of 1 second to 45 minutes; input less than 70 ma; multiple switch closures available. Surpasses mil specs.—*Acton Laboratories, Inc., Space Instrumentation Div., 533 Main St., Acton, Mass.*

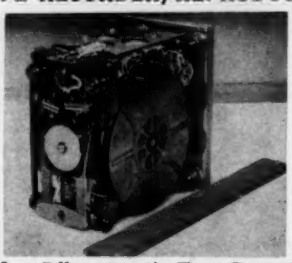
CIRCLE 362 ON READER-SERVICE CARD

ISOLATION TRANSFORMERS

New electrostatically shielded 115 to 115 volt transformers with power ratings from 5 to 500 VA are enclosed in MIL-T-27A cans; 1 to 2.5 KVA units in special cans are also available. Primary to secondary capacitance is less than 0.5 $\mu\mu f$.—*Topaz Transformer Products, Inc., 4995 Weeks Ave., San Diego 10, Calif.*

CIRCLE 363 ON READER-SERVICE CARD

TAPE RECORDER/REPRODUCER



New 5-lb magnetic Tape Recorder/Reproducer records, reproduces and erases teletype communications between ground and satellite. Unit will relay messages from Army's Courier satellite, will operate in outer space for more than a year.—*Datalab Div., Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.*

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Within these three comprehensive Marsh groups you have the world's widest (yes, and wisest) selection of pressure gauges. These groups of gauges are not *grades* ...they are *kinds*...the MARSH kind... which means that each gauge, within the scope of its rated use, is the BEST of its kind!

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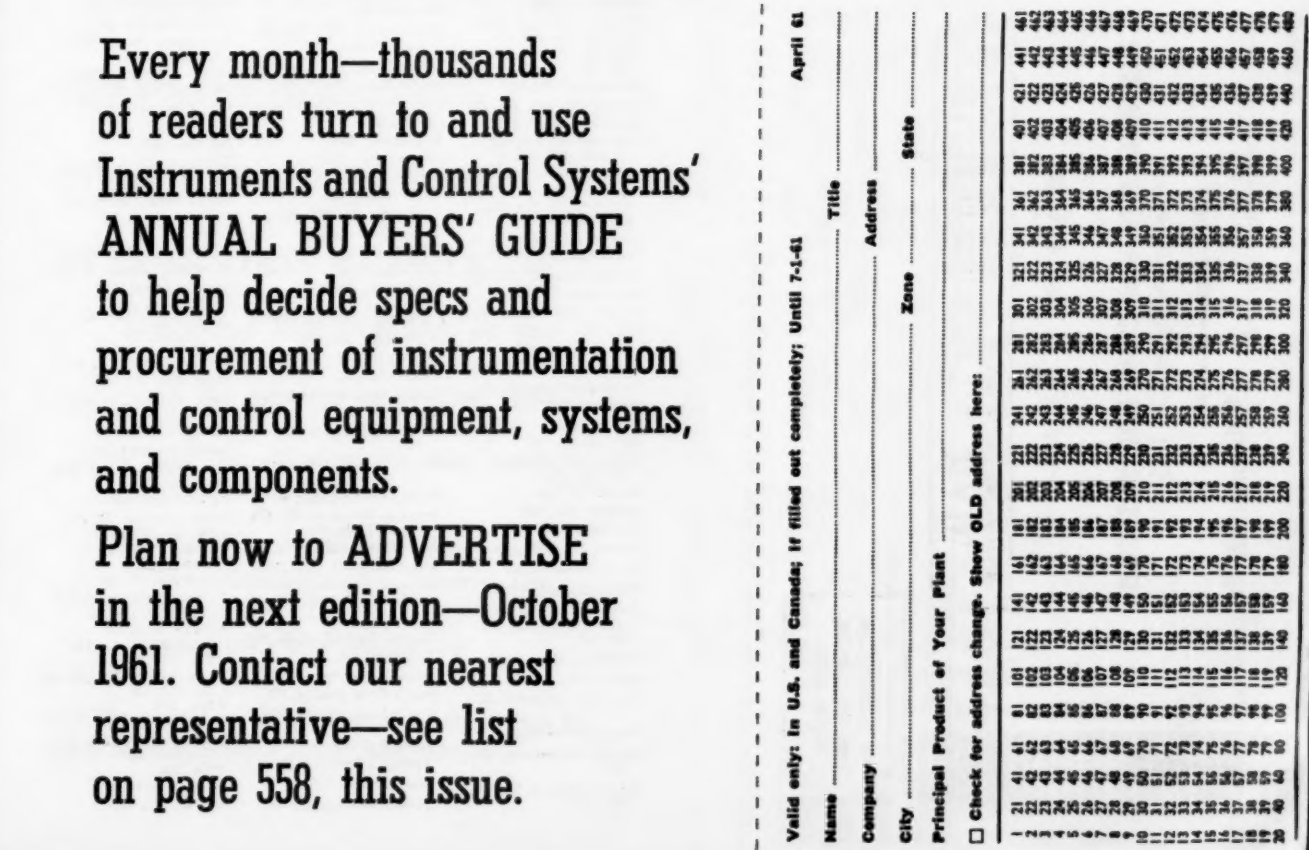

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16	36	56	76	96	116	136	156	176	196	216	236	256	276	296	316	336	356	376	396	416	436	456
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297	317	337	357	377	397	417	437	457
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298	318	338	358	378	398	418	438	458
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299	319	339	359	379	399	419	439	459
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6	46	86	126	166	206	246	286	326	366	406	446	486	526	566	606	646	686	726	766	806
7	47	87	127	167	207	247	287	327	367	407	447	487	527	567	607	647	687	727	767	807
8	48	88	128	168	208	248	288	328	368	408	448	488	528	568	608	648	688	728	768	808
9	49	89	129	169	209	249	289	329	369	409	449	489	529	569	609	649	689	729	769	809
10	50	90	130	170	210	250	290	330	370	410	450	490	530	570	610	650	690	730	770	810
11	51	91	131	171	211	251	291	331	371	411	451	491	531	571	611	651	691	731	771	811
12	52	92	132	172	212	252	292	332	372	412	452	492	532	572	612	652	692	732	772	812
13	53	93	133	173	213	253	293	333	373	413	453	493	533	573	613	653	693	733	773	813
14	54	94	134	174	214	254	294	334	374	414	454	494	534	574	614	654	694	734	774	814
15	55	95	135	175	215	255	295	335	375	415	455	495	535	575	615	655	695	735	775	815
16	56	96	136	176	216	256	296	336	376	416	456	496	536	576	616	656	696	736	776	816
17	57	97	137	177	217	257	297	337	377	417	457	497	537	577	617	657	697	737	777	817
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edited by Milton Aronson. This definitive practical text on weight instrumentation begins with a survey of fundamentals, progresses through basic weighing techniques, typical applications, and typical commercial equipment. Paper, 78 pages, 1961.

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by Chester S. Beard and Fred D. Marton. Covers regulators for pressure, vacuum, flow, temperature, level, gas systems, and pump discharge. Also safety, relief, and safety-relief valves; and automatic emergency valves, including shut-off valves for oil and gas transmission lines. Paper, 204 pages, illustrated, 1959.

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Digital Techniques for Computation and Control **$6.00**

by Klein, Morgan, and Aronson. Includes code arithmetic, logical networks, multiplexing, conversion, data reduction, digital process control, two-terminal relay circuits, counting techniques, digital computers of all types, computer programming, digital differential analyzers, and basic principles, basic circuits, combined analog-digital equipments, components and available commercial equipments. Cloth, 394 pages, illustrated.

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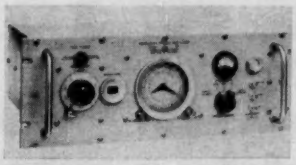
FREQUENCY DIVIDER/CLOCK



New Model 113AR Frequency Divider and Clock permits adjustment of frequency or time standards for greater absolute accuracy, simplifies obtaining detailed records of drift rates or time or frequency differences between oscillators in widely separated systems. Propagation path errors can be averaged out; Doppler errors virtually eliminated; 10-μsec time comparison capability.—*Hewlett-Packard Co.*, 1501 *Page Mill Rd., Palo Alto, Calif.*

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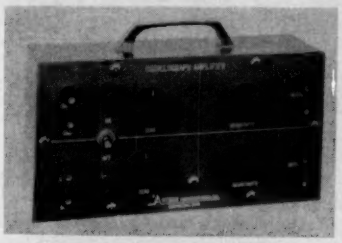
OSCILLOGRAPH AMPLIFIER



New low-cost oscillograph amplifier Model T249 has two independent amplifier channels, a common power supply, and zeroing and sensitivity adjustments on each channel. Input impedance is 100 kilohm and frequency response is dc to 10 kc. Maximum output is 8 milliamps and maximum sensitivity is 2 ma/v.—*Avtron Mfg. Inc.*, 10409 *Meech Ave., Cleveland*, 5, *Ohio.*

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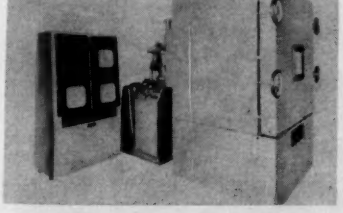
ENVIRONMENTAL CHAMBER



New chamber Model WF-27-125+350 has range from −125° to 350°F. Pull down over the entire range requires 90 minutes; heat up takes 60 minutes. Special vacuum equipment simulates 4 x 10^{-6} mm Hg in 45 minutes. Inside dimensions are 36" x 36" x 36".—*Webber Manufacturing Co., Inc., Box* 217, *Indianapolis* 6, *Ind.*

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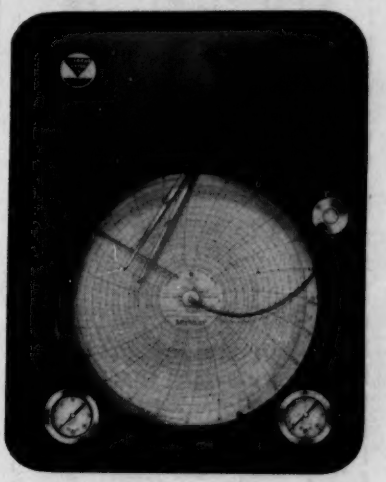
AMERICAN®



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- Proportional Band easily widened without disconnecting instrument tubing.
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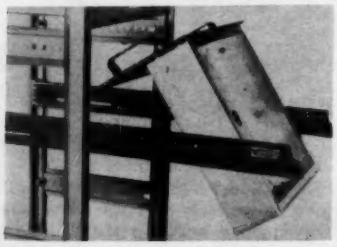
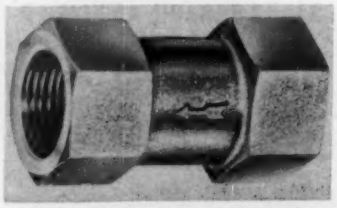
TILTING CHASSIS SLIDE



New slide design SS-300-T for rack-mounted equipment allows chassis to tilt up for quick access. With capacity of 185 lb at full extension, the slide will mount a full 17" wide chassis in any standard 19" panel rack cabinet. It is 3" high and available in stock lengths of 14" to 24".—*Christman Industries, Inc.*, 1562 61 *St., Brooklyn* 19, *N. Y.*

CIRCLE 368 ON READER-SERVICE CARD

CONTROL VALVE



New L-P-D (low pressure drop) Measurflo Control Valve automatically compensates for pressure surge and pressure drop to maintain one constant flow rate. Built for pressures to 160 psi, 49 flow rates from 2/10 to 50 gpm, pipe sizes from ¼"-1¼", noiseless, self-cleaning, neoprene diaphragm. Folder 2305-7.—*Automatic Controls Div., Hays Manufacturing Co., Erie, Pa.*

CIRCLE 369 ON READER-SERVICE CARD

AIRBORNE TAPE MEMORY

New MTR-800 medium-sized (9 lb) tape recorder designed to eliminate loss of telemetry information during re-entry missile phases, or in over-the

horizon transmissions, is shown with 24 oz MTR-362 and 12 lb MTR-1200 recorders, also noted for operating under the roughest environmental conditions. Records on 7 or 14 channels.—*Leach Corporation, Special Products Div.*, 516 *E. Compton Blvd., Compton, Calif.*

CIRCLE 370 ON READER-SERVICE CARD

MODULAR CONSOLE RACK

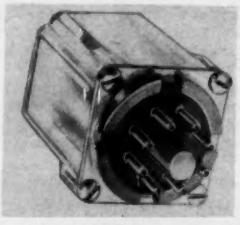
New Prem-O-Rak Modular sloped Front Console provides 17½" panel space sloped front area 19° from

vertical. Frames are finished in gray Hammertone, Panels in brown Hammertone finish.—*Premier Metal Products Co.*, 337 *Manida St., New York* 59, *N. Y.*

CIRCLE 464 ON READER-SERVICE CARD

PLUG-IN RELAYS

Multipole plug-in sensitive relays with high-heat polystyrene covers in



DPDT and 3 PDT operate from as low as 25 milliwatts per pole, dc only. Contacts are rated 5 amp 28v dc or 115v ac. Coil resistances to 20,000 ohms.—*Kurman Electric Co.*, 191 *Newel St., Brooklyn* 22, *N. Y.*

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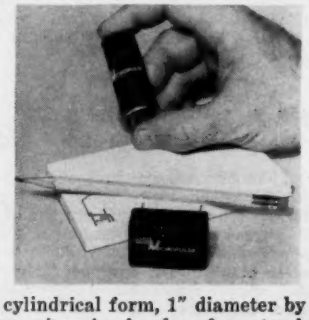
DELAY LINES

New miniature lumped-constant delay lines having delay times of 0.5, 1.0, 2.0 and 3.0 μsec accurate to ±3% and in input impedances of 300, 500 and 1000 ohms, ±10%, are available



in cylindrical form, 1" diameter by 2" long nine-pin header for standard tube socket mounting or in rectangular form for use with printed circuitry.—*The Ralph M. Parsons Co., Electronics Div.*, 151 *South De Lacey Ave., Pasadena, Calif.*

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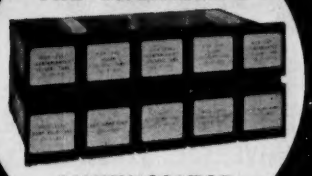
SCAM®

DE-LINE

THE ENGINEER'S



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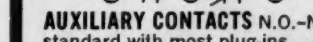

AUXILIARY CONTACTS N.O.-N.C. standard with most plug-ins.

SEQUENCE OPTION after installation by means of independent slide switch at each point.

DE-LINE plug-ins are self-policing. Systems are rugged and dependable.

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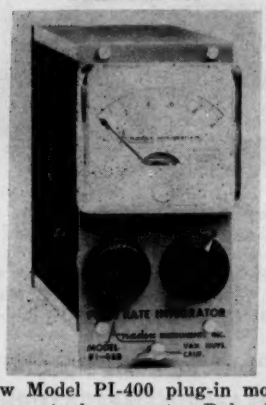
FREQUENCY-TO-DC CONVERTER



New Model PI-400 plug-in module frequency-to-dc converter Pulse Rate Integrator furnishes a low impedance dc output voltage and current precisely proportional to the frequency or pulse rate of the input. Precision output of up to 5 volts is accurate to 0.1%, with exceptional line and temperature stability.—*Anadex Instruments, Inc.*, 14734 *Arminta St., Van Nuys, Calif.*

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DIGITAL ENCODER

New Model EP-13B shaft-position Digital Encoder with 13-bit binary output employs non-contacting magnetic readout. Only bearings and gears affect life, permitting operation in any environment to 10,000 rpm with any number of readouts. Applications in digital control and data-logging equipment in military and industrial environments.—*Electro-Mechanical Research, Inc., Box* 3041, *Sarasota, Fla.*

CIRCLE 372 ON READER-SERVICE CARD

R-F POWER BRIDGE

New precision R-F power bridge Model PB-1 is designed for use with 200-ohm bolometer mounts using either 4.5 or 8.75 ma barretters or a pair of 13-ma thermistors. Accuracy of 14% in substituted power is achieved between 500 μw and 20 mw.—*Weinschel Engineering*, 10503 *Metropolitan Ave., Kensington, Md.*

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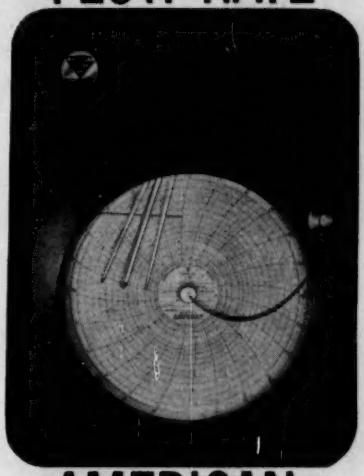

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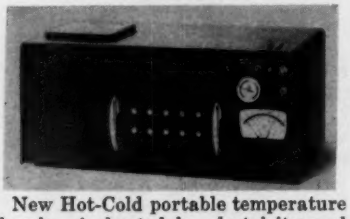
CIRCLE 151 ON READER-SERVICE CARD

CDA ALARM

New 110-v synchronous motor safety device for installation in the receivers of government-sponsored National Emergency Alarm Repeater prevents accidental tripping of the alarm by stray electrical fields.—*Controls Co. of America, 9555 Soreng Ave., Schiller Park, Ill.*

CIRCLE 374 ON READER-SERVICE CARD

PORTABLE TEMPERATURE CHAMBER



New Hot-Cold portable temperature chamber is heated by electricity and cooled by either liquid CO_2 or dry ice, is regulated to any temperature in the −100°F to 500°F to within ±½°F. Can be programmed by auxiliary timer to alternate between high and low temperatures.—*Delta Design, Inc., 7460 Girard Ave., La Jolla, Calif.*

CIRCLE 375 ON READER-SERVICE CARD

STRAIN GAGE CALIBRATION

Calibration of strain gages at temperatures at which they are to be used is simply accomplished by new unit.

Gages are attached to a constant strength cantilever beam which is placed in bending by a stepped sliding block at the beam's free end. This subjects gages to known strains, and gage resistance measurements provide gage factor. Can be used inside Dewar vessel to −425°F or in oven to 500°F or more.—*Cryogenic Research Co., P.O. Box 881, Boulder, Colo.*

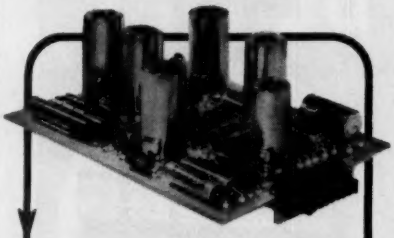
CIRCLE 376 ON READER-SERVICE CARD

INCREMENTAL MULTIMETER

New type of instrument expands increments of any range of associated multimeter to ±1% of full-scale value of range. Used with a 5-mv sensitivity external servo recorder, it displays variations in any parameter that may be represented as a voltage, current or resistance, such as line voltage variations.—*Tensor Electric Development Co., Inc., 1873 Eastern Parkway, Brooklyn 33, N. Y.*

CIRCLE 377 ON READER-SERVICE CARD

Your best buy in operational amplifiers ?



THE PHILBRICK USA-4J UNIVERSAL STABILIZED AMPLIFIER!

Choose this amplifier when the need for exceptional reliability justifies the price, and enjoy the bonus of remarkably high performance. Its reliabilty statistics prove it the best buy in the industrial and process control fields, although the USA-4J was originally designed for military use.

- **LOW DRIFT AND NOISE:** well under 50 microvolts rms.
- **GAIN: 100 MILLION** minimum open loop at dc; greater than unity at one megacycle; output, over ±100 volts.
- **COOL RUNNING:** tubes and resistors operate at a fraction of wattage ratings; capacitors operate generally below ⅓ their voltage ratings.
- **MIL STD PARTS:** used exclusively.
- **EMINENTLY SENSIBLE COST:** Just **$185**

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CIRCLE 152 ON READER-SERVICE CARD

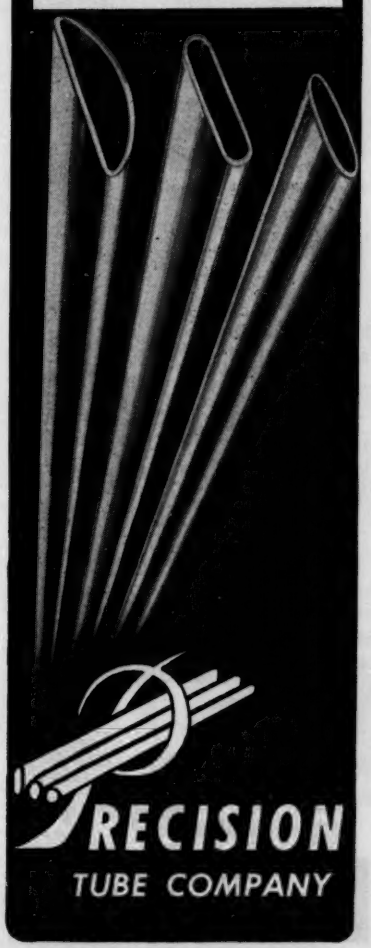
BOURDON TUBING

ACCURATE ONE INCH TO ONE MILE

Constant wall thickness . . . consistent spring properties . . . exact duplication . . . whether a "C", a helix, or a spiral—Precision Bourdon Tubing meets all these requirements. Precision's modern production facilities offer you instrument tubing to meet your most exacting specifications—tubing preformed or straight.

Precision also offers Coaxitube, a metal shielded wire consisting of an inner conductor, insulation and seamless non-ferrous metal tubular shield forming a coaxial pair of conductors. Semi-rigid equivalents to all RG/U cables.

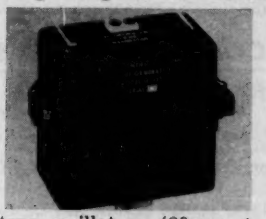
Write for full details on "Precision Tubing For Precision Instruments" to Dept. 3, Precision Tube Corporation, North Wales, Pa.



CIRCLE 153 ON READER-SERVICE CARD

TONE GENERATOR

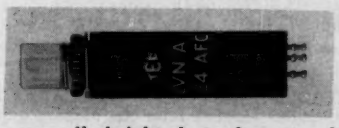
New 10-tone generator for missile telemetry and related applications. 28-v dc gate signals turn on respective tone oscillators (30 cps to 400 cps) producing composite signal for modulation of voltage-controlled subcarrier oscillator or line transmission. —*Alto Scientific Co., Inc.*, 855 *Commercial St.*, *Palo Alto, Calif.*



CIRCLE 378 ON READER-SERVICE CARD

LOW VOLTAGE NEON LAMPS

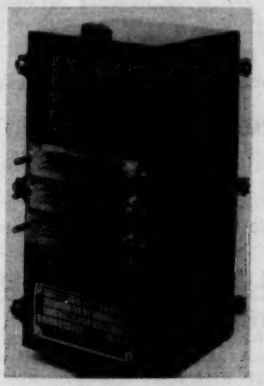
Miniature LVN transistor driven neon lamps combine shock resistance and long service life of neon with advantages of low voltage supply, have two equally bright electrodes, use only 150 mw power. New 3-terminal unit lights only on application of input signal.—*Transistor Electronics Corp.*, 3357 *Republic Ave.*, *Minneapolis* 26, *Minn.*



CIRCLE 379 ON READER-SERVICE CARD

SOLID-STATE COMMUTATOR

New Series ES 35 solid-state commutator, supplied in standard scan rates up to 25 kc and in different models of from 2 to 100 channels, accepts signal ranges of 0-10 mv or 0-5 v. Crosstalk is only 0.1% of input signal and linearity is within ±0.1% deviation from straight line. Contact resistance 25 ohms max. Operates in temperatures to 125°C max, acceleration to 40 G and in explosive atmospheres.—*Electronic Systems Development Corp.*, 1484 *East Main St.*, *Ventura, Calif.*



CIRCLE 380 ON READER-SERVICE CARD

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PIPETTOR

Eliminates Dangers of Contamination Found In Conventional Pipetting!

Now, a pipettor that operates precisely, simply, perfectly with just one hand. Does away with the dangers and possible contamination involved in usual pipetting procedures. What's more, ACCROPET is specially designed to assure accurate discharge and filling at great speeds.

Compactly shaped of high temperature polypropylene which can withstand temperatures up to 320°F. "O" ring construction provides exceptionally accurate, dependable, leak-proof action. Rubber tubing connection permits unusual flexibility, helps eliminate pipet breakage.

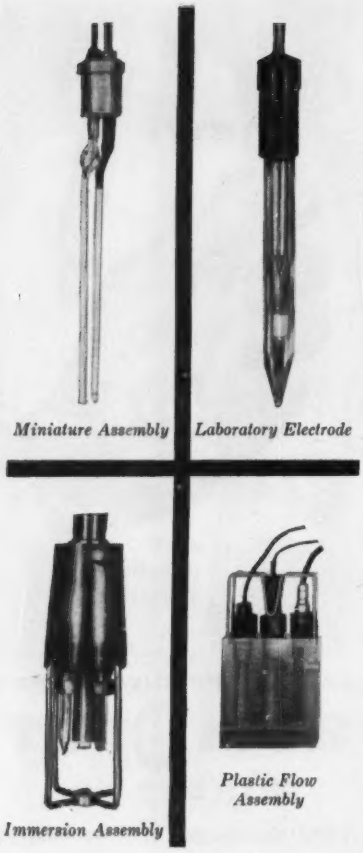
PP-1000 Accropet, ultramicro size. For all pipets up to and including 2/10 cc., and especially recommended for Lambda-pettes. Packed singly or in cartons of six. **$3.50 each, carton of six $16.80**

PP-1200 Accropet, micro size. For all pipets up to and including 2 cc., and red and white blood pipets. **$4.95 each, carton of six $23.70**

See your local laboratory supply dealer.

MANOSTAT Corporation
26 N. Moore St., New York 13, N. Y.

CIRCLE 154 ON READER-SERVICE CARD



To measure pH precisely start with L&N Electrodes!

Widely used both in laboratories and on process lines, L&N Electrodes have earned universal recognition for dependable, precise measurements of pH and redox.

Only L&N's specially developed glass composition provides minimum solubility to extend electrode life . . . minimum sodium error, to broaden the detection range.

If you're looking for a quality line of electrodes, ask for our informative Data Sheets: E-95(1) describing laboratory electrodes and NS5(1) describing industrial electrodes and mountings. Write Leeds & Northrup, 4955 Stenton Ave., Phila. 44, Pa.

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CIRCLE 155 ON READER-SERVICE CARD

ICS NEW INSTRUMENTS

CONTROL SYSTEMS

EVAPORATOR CONTROL SYSTEM. 2-page Bulletin 4-4 describes 3-element effluent (heavy liquor) density control system for pulp paper mills.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

CIRCLE 381 ON READER-SERVICE CARD

AUTOMATIC BATCH CONTROL. 4-page brochure describes Batchetron 600 automatic batching control system for concrete and asphalt proportioning.—Electronics Div., Fairbanks, Morse & Co., 505 Oakland Ave., West Hartford, Conn.

CIRCLE 382 ON READER-SERVICE CARD

VALVES

VALVE. 4-page Bulletin 301 describes bonnetless knife gate valve and applications.—DeZurik Corp., Sartell, Minn.

CIRCLE 383 ON READER-SERVICE CARD

REGULATORS. 4-page Bulletin J-DI describes Ductile Iron Regulators and Control Valves.—OPW-Jordan, 6013 Wiehe Rd., Cincinnati 13, Ohio.

CIRCLE 384 ON READER-SERVICE CARD

TEMPERATURE

THERMOMETERS. 20-page Catalog 155 illustrates and describes bi-metal actuated dial thermometers.—Manning, Maxwell & Moore, Inc., 250 E. Main St., Stratford, Conn.

CIRCLE 385 ON READER-SERVICE CARD

THERMOSTATS. 4-page Bulletin 3500 describes Type G commercial thermostats, featuring exposed or enclosed bimetal disc thermal elements.—Stevens Manufacturing Co., Inc., Box 1007, Mansfield, Ohio.

CIRCLE 386 ON READER-SERVICE CARD

THERMAL CONDUCTIVITY DETECTORS. 3-page Data Sheet LOE-6 details Thermal Conductivity Detectors.—Loe Engineering Co., 2092 N. Lincoln Ave., Altadena, Calif.

CIRCLE 387 ON READER-SERVICE CARD

FLOW, LIQUID LEVEL

FLOWMETERS, TOTALIZERS. 8-page Spec 51-2860 details 6 new transistorized totalizers and batch controllers for use with 2 new turbine flow meters (described in 6-page Spec 10C15-05).—Fischer & Porter Co., 852 Jacksonville Rd., Warminster, Pa.

CIRCLE 388 ON READER-SERVICE CARD

LEVEL CONTROLS. 4-page Bulletin 334 describes electronic floatless liquid level controls.—B/W Controller Corp., 2200 E. Maple Rd., Birmingham, Mich.

CIRCLE 389 ON READER-SERVICE CARD

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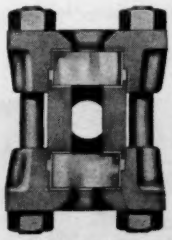
HIGH PRESSURE GAUGES

USED IN **REFINERIES** *AND* **CHEMICAL PLANTS** *THROUGHOUT THE WORLD*



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Single or Multiple Sections

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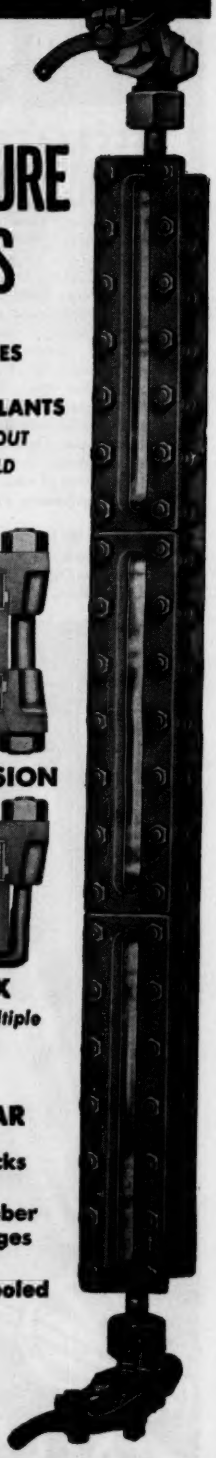

SEND FOR **COMPLETE CATALOGUE**

STRAHMAN VALVES, Inc.
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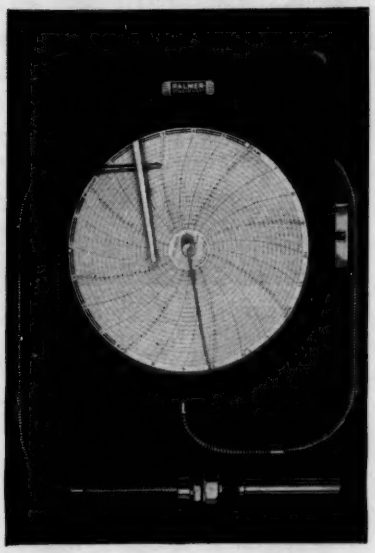
CIRCLE 156 ON READER-SERVICE CARD

PALMER

MERCURY ACTUATED RECORDERS

Into this modern Mercury Actuated Recorder has gone all the skill of Palmer Master Craftsmen



Readings are clearer, smoother and more precise than ever thought possible. In fact readings are so amazingly improved that maintenance is never needed under normal uses.

Recording Thermometers feature twelve inch die-cast aluminum case with black wrinkle or white satin finish. Single or multiple pen construction. Electric or spring wound clock, 24 hour or 7 Day Revolution. Flexible Armor and bulb of stainless steel. Ranges: —40 to 1000°F. or Equivalent in °C.

Send for Bulletin No. 45
Consult your Classified Directory

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PALMER THERMOMETERS, INC.
Mfrs. of Industrial Laboratory, Recording and Dial Thermometers
Cincinnati 12, Ohio

CIRCLE 157 ON READER-SERVICE CARD

COMPONENTS. 6-page folder describes servo motors, motor-tachometers, gearhead-motors, etc.—Bowmar Instrument Corp., 8000 Bluffton Rd., Fort Wayne, Inc.

CIRCLE 390 ON READER-SERVICE CARD

CHECK-OUT SYSTEM. 8-page bulletin describes Speed-Tronik "all-parameter" automatic testing system.—Audiotronics Co., Box 2187, Dayton 29, Ohio.

CIRCLE 391 ON READER-SERVICE CARD

TEST CHAMBER. 4-page bulletin details operative principle and features of MC Temp Test Chamber.—Statham Instruments, Inc., 12401 W. Olympic Blvd., Los Angeles 64, Calif.

CIRCLE 392 ON READER-SERVICE CARD

ATTENUATORS. 4-page Bulletin 500 describes microwave waveguide and coaxial attenuators.—PRD Electronics, Inc., 202 Tillary St., Brooklyn 1, N. Y.

CIRCLE 393 ON READER-SERVICE CARD

THERMOELECTRIC DEVICES are described in 2-page reprint.—Materials Electronic Products Corp., 990 Spruce St., Trenton 8, N. J.

CIRCLE 394 ON READER-SERVICE CARD

RESET ACROTIMER. 4-page folder gives detailed information on External Clutch Reset Timer, opening or closing switches after an adjustable period of time.—Haydon Div., General Time Corp., 245 East Elm St., Torrington, Conn.

CIRCLE 395 ON READER-SERVICE CARD

THERMOCOUPLE PYROMETERS. 4-page Bulletin 8-60 fully describes 3 types of pyrometer-millivoltmeters for measuring temperatures with thermocouples. Lists scale ranges and selection of thermocouple types.—Lewis Engineering Co., Naugatuck, Conn.

CIRCLE 396 ON READER-SERVICE CARD

INDUSTRIAL HUMIDIFICATION. 2-page bulletin on Humidification for Data Processing covers the importance of controlling both temperature and relative humidity to retain accuracy of computing machinery.—Walton Labs., Inc., Irvington 11, N. J.

CIRCLE 397 ON READER-SERVICE CARD

PORTABLE THERMOCOUPLE calibration stand and thermocouple reference junction compensator are described in 2-page Catalog Supplement 206.—Harco Laboratories Inc., 77 Olive St., New Haven, Conn.

CIRCLE 398 ON READER-SERVICE CARD

PHYSICS RESEARCH LABS' test facilities are described in 4-page brochure.—Physics Research Laboratories, Inc., Box 555, Hempstead, N. Y.

CIRCLE 399 ON READER-SERVICE CARD

PLOTTING BOARDS. 5-page Form 80-392 describes transistorized XY plotting boards, single and dual arm, with electroluminescent panels for backlighting.—Computer Systems, Inc., Culver Rd., Monmouth Junction, N. J.

CIRCLE 400 ON READER-SERVICE CARD

LAMPS. 4-page Catalog 116 describes incandescent, fluorescent and magnifying lamps for use over assembly and inspection benches. etc.—Luxo Lamp Corp., Dock St., Port Chester, N. Y.

CIRCLE 401 ON READER-SERVICE CARD

NOW

available from stock

MB model N504 INTEGRATOR AMPLIFIER

- Measure acceleration, velocity, or displacement with conventional accelerometers and vibration meters.
- Measure acceleration or velocity from accelerometer input with standard voltmeters.
- Convert accelerometer signals to velocity for automatic control of vibration exciter displacement, velocity or acceleration.
- Eliminate need for cathode follower and power supply.

SPECIFICATIONS

Frequency Response:	**Amplify Position** (5 cps filter) 10—10,000 cps ± 2% 5—10,000 cps ±7%
	Integrate Position (—6 db/octave) 10—2,000 cps ± 5% 5—2,000 cps ±10%
Sensitivity:	**Amplify Position** Maximum gain = 100
	Integrate Position 1 mv(rms)/"g" peak converted to 96.3 mv (rms)/in./sec.(rms)
Input Impedance:	Greater than 200 megohms
Output Impedance:	Less than 600 ohms

Complete technical details in Bulletin 131. Write...

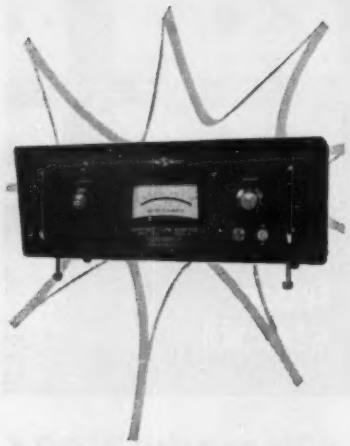
MB ELECTRONICS

A DIVISION OF TEXTRON ELECTRONICS, INC.
1103 State Street, New Haven 11, Conn.

CIRCLE 158 ON READER-SERVICE CARD

HASTINGS MASS FLOW MONITOR

VARIABLE RANGE



This HASTINGS MASS FLOW MONITOR represents the latest developments in electrical measurements of predetermined air or gas flow rates. Operating on the time proven principle of the HASTINGS PATENTED THERMOPILE, this monitor features:

- Standard flow tubes for ranges from 50 to 200,000 STD cc/min.
- "Correct" flow rate readings
- Remote indication, control, and recording
- Center reading indicator
- Adjustable sensitivity
- Extreme sensitivity to low flow rates
- High overload capacity
- Negligible pressure drop
- Flow is a mass flow measurement
- Quick resetting for different flow rates
- Cabinet or rack panel mounting

The NEW HASTINGS MASS FLOW MONITOR is composed of the power supply with the indicator and the flow tube which contains the fully compensated HASTINGS THERMOPILE. The flow tube can be installed directly in the line wherever convenient.

For more detailed information send for Specification Sheet No. 503 and for full information on HASTINGS complete line of vacuum instruments send for Catalog No. 300.

HASTINGS-RAYDIST, Inc.
Hampton, Virginia PArk 3-6531

CIRCLE 159 ON READER-SERVICE CARD

WIRE, CONNECTORS

MINIATURE CONNECTORS. 44-page Form 20-1060 describes and illustrates Series 20 rectangular plug and socket connectors, contact sizes from 4 to 104 with solder cup, turret and taper pin solderless terminations.—DeJur-Amsco Corp., 45-01 Northern Blvd., Long Island City 1, N. Y.

CIRCLE 402 ON READER-SERVICE CARD

MINIATURE PLUGS. 12-page Catalog KQ/KR-1 describes Cannon Plugs that meet requirements of aircraft and missile applications.—Cannon Electric Co., 3208 Humboldt St., Los Angeles 31, Calif.

CIRCLE 403 ON READER-SERVICE CARD

FINE WIRE compositions and properties for electronics applications are described and tabulated in 4-page bulletin.—Consolidated Reactive Metals, Inc., 115 Hoyt Ave., Mamaroneck, N. Y.

CIRCLE 404 ON READER-SERVICE CARD

MECHANICAL, ELECTROMECHANICAL COMPONENTS

FASTENERS. 2-page Spec Sheet details threads and dimensions for all head types of nylon screws.—Gries Reproducer Corp., 400 Beechwood Ave., New Rochelle, N. Y.

CIRCLE 405 ON READER-SERVICE CARD

GEARS. 128-Page Catalog 5A details stock precision gears and instrument clamps.—Perfect Gear and Instrument Corp., Subs. Liberty Electronics Corp., 339 S. Isis, Inglewood, Calif.

CIRCLE 406 ON READER-SERVICE CARD

FASTENINGS. 2-page bulletin details fast delivery on short runs of studs and threaded rod.—Star Stainless Screw Co., 699 Union Blvd., Paterson 2, N. J.

CIRCLE 407 ON READER-SERVICE CARD

SEAL RINGS. 4-page bulletin describes Seal Ring Assembly that seals off large differential pressures in applications where O-ring seals extrude and fail.—Bowen Itco, Inc., Box 4587, Houston 13, Texas.

CIRCLE 408 ON READER-SERVICE CARD

GASKETS. 6-page folder details Teflon pipe and flange gaskets, adapters, specialty items.—Chem Flow Corp., 177 Patterson Ave., Little Falls, N. J.

CIRCLE 409 ON READER-SERVICE CARD

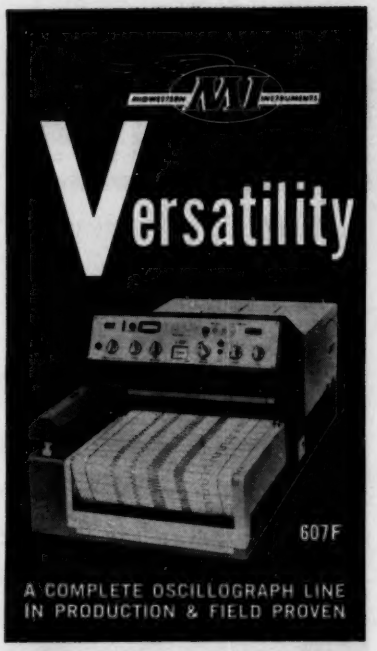
FABRICATION

SOLDERING, BRAZING. 4-page brochure describes economic automation processes in soft soldering and silver brazing.—Fusion Engineering, 17921 Roseland Ave., Cleveland 12, Ohio.

CIRCLE 410 ON READER-SERVICE CARD

LAPIDARY. 12-page brochure discusses history, materials, and techniques of polishing semi-precious gems.—Carborundum Co., Box 337, Niagara Falls, N. Y.

CIRCLE 411 ON READER-SERVICE CARD



MIDWESTERN'S direct recording line offers you a choice of models to meet your specific data recording needs. 19 different models in the 600 Series allow a combination of size, data channels, and many other functional features in a wide price range. These precision recorders, in production and field proven, are ready to meet your immediate data logging requirements whether they be in a complex research and development system, or for medical or educational uses, quality control, production, or environmental tests.

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also manufacturers of Magnecord "professional" tape recorders
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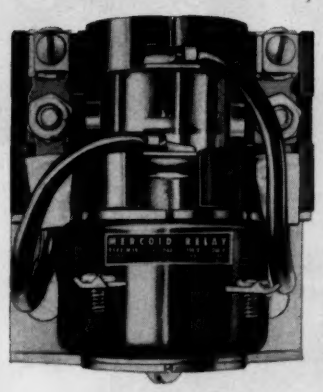
CIRCLE 160 ON READER-SERVICE CARD

35 AMP

* 120V. Non-Inductive A.C. heater loads

Plunger Type

MERCURY RELAY



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MERCOID

If you need reliability and durability, this quality built relay by Mercoid is your answer.

For heavy duty loads, such as resistance heating, (domestic, commercial, industrial)—heat treating furnaces, drying equipment, welding, lighting, illuminated signs, score boards.

Hermetically sealed mercury to mercury contact provides visible on-off operation. Silent and chatterless. Quickly mounted, easily wired. Speeds up to 100 operations per minute.

Available normally open;

CONTACT RATING:

LOAD			*NON INDUCTIVE HEATER LOADS	
	AC	DC	AC ONLY	
120V.	30A.	15A.	120V.	35A.
240V.	20A.	10A.	240V.	25A.
440V.	8A.	—	440V.	10A.

WRITE FOR BULLETIN 0-20

THE MERCOID CORPORATION
4211 Belmont Ave., Chicago 41, Ill.

CIRCLE 161 ON READER-SERVICE CARD

ELECTRICAL, ELECTRONIC INSTRUMENTS

VOLTAGE COMPARATORS. 6-page bulletin describes Series 50 transistorized voltage comparators used for critical go/no-go applications and Model 51 voltage comparison amplifier.—Non Linear Systems, Inc., Del Mar, Calif.

CIRCLE 412 ON READER-SERVICE CARD

PHASE METERS. 4-page brochure describes precision phase meters Types 405, 405H, 405L. Separate 2-page leaflets cover continuously variable delay lines Type 505-9, mini pre-amp Types A102 and A102S, and precision phase generator-shifter Types 208, 208A.—Ad-Yu Electronics Lab, Inc., 249 Terhune Ave., Passaic, N. J.

CIRCLE 413 ON READER-SERVICE CARD

MISCELLANEOUS

OPERATIONAL AMPLIFIERS. 6-page reprint reviews use of operational amplifiers in precision current regulators, and in accelerator beam control systems, described in papers by Karl Eklund.—George A. Philbrick Researches, Inc., 285 Columbus Ave., Boston 16, Mass.

CIRCLE 414 ON READER-SERVICE CARD

PANEL INSTRUMENTS. 24-page Bulletin 3-15 illustrates and describes a-c and d-c meters.—Federal Pacific Electric Co., Fifty Avenue, L., Inc., Newark 1, N. J.

CIRCLE 415 ON READER-SERVICE CARD

MEDICAL APPARATUS. 4-page brochure illustrates and describes several types of lung-function apparatus made by Godart-Mijnhardt NV, Holland.—Instrumentation Associates Inc., 17 West 60th St., New York 23, N. Y.

CIRCLE 416 ON READER-SERVICE CARD

PLASTIC CABLING. multilayer circuitry and laminates are described in 8-page Bulletin S-9.—International Resistance Co., 401 N. Broad St., Phila. 8, Pa.

CIRCLE 417 ON READER-SERVICE CARD

DRAWING INSTRUMENTS. 124-page Catalog-G describes, illustrates, and prices drawing sets, instruments, templates, computing and measuring devices, magnifiers, etc.—Alvin & Co., Inc., Windsor, Conn.

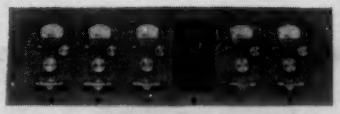
CIRCLE 418 ON READER-SERVICE CARD

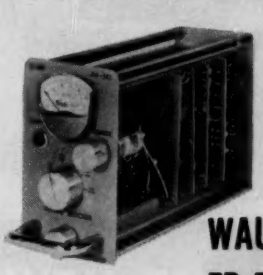
SOLDERING IRONS. 4-page Catalog GEC-1545 describes production soldering irons (6, 115, 120, 230 v; 12 to 1250 w) for use on all electronic equipments, meters, and instruments.—General Electric Co., Schenectady 5, N. Y.

CIRCLE 419 ON READER-SERVICE CARD

OVENS. 12-page brochure describes characteristics of oven and air control cabinets, features oven's Power-O-Matic integral temp control and Range-Lock apparatus.—Soiltest, Inc. 4711 W. North Ave., Chicago 39, Ill.

CIRCLE 420 ON READER-SERVICE CARD





WAUGH FR-500

MODULAR Frequency-to-D.C. CONVERTER

The new Waugh FR-500 is a modular frequency-to-d.c. converter designed to permit the monitoring or recording of signals from several sources simultaneously.

Five converter modules mount in a 7x19" rack panel, with six converters on a 24" panel.

Each converter produces three outputs precisely proportional to the frequency of the a.c. input signal from flow sensors, tachometers, photo cells, electro-magnetic coils, or FM systems. Output may be read directly on the panel meter. Pulse and d.c. outputs are also provided to drive oscillographs, counters, and a wide variety of other electronic indicators, recorders or controllers.

A power supply for up to 25 converters, and a master calibration oscillator, with an an accuracy of ±.01% of reading fit on a single panel which can be mounted on the same rack as the FR-500. Individual, integral power supplies are also available with each module.

SPECIFICATIONS

Frequency Range	5 cps to 3.2 kc. (10 kc. available)
Input Amplitude	5 mv. to 100 volts
Linearity	0.1% of full scale
Ripple	±0.1% full scale peak-to-peak max.
Pulse Output	10 ma. into 250 ohms
D.C. Output	0 to 5 volts

Request Bulletin 112 for complete specifications

Waugh *Engineering Representatives in Principal Cities*

WAUGH ENGINEERING COMPANY

7842 Burnet Avenue, Van Nuys, Calif.
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CIRCLE 162 ON READER-SERVICE CARD

A major breakthrough in temperature measurements!

THE NEW thermo-ref solid-state thermocouple reference

The new Genistron Thermo-Ref provides a constant reference temperature of 100°C., ±0.1°C., with a 10-channel uniformity of ±0.1°C. Maximum drift is less than 0.5°C. over an ambient temperature range of −55°C. to +85°C. Power consumption is a nominal of 1.0 watts over a voltage variation of 95 to 125 volts AC. These specifications and its small size and light weight make the Thermo-Ref ideal for airborne applications. Standard models are available for reference temperatures of 100°C., 121°C. and 150°C.

The Thermo-Ref measures 3⅛"x3¼"x2" and weighs approximately 12 ounces. Packaging and environmental conditions meet or exceed MIL-E-5272 and MIL-E-16400.

Write for complete technical information.

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A subsidiary of Genisco Inc.
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CIRCLE 163 ON READER-SERVICE CARD

FLOW METERING. 8-page Bulletin 100.20 itemizes 10 Differential Producers, covers comprehensive range of applications. 4-page Bulletin 400.20-1 describes Shuntflo Meter for measuring steam, air or gas flow.—B-I-F Industries, Inc., Providence 1, R. I.

CIRCLE 421 ON READER-SERVICE CARD

PRESSURE, WEIGHT

PLATFORM SCALE. 4-page Catalog 161 describes Hydroscale Mobile Platform Scale that attaches to any forklift truck, lifts and weighs in one operation.—Hydroway Scales, Inc., Box 531, Oakridge Sta., Royal Oak, Mich.

CIRCLE 422 ON READER-SERVICE CARD

PRESSURE INDICATOR. 2-page Data Sheet P-60236 describes redesigned Teledyne Model 236 Pressure Indicator.—Taber Instrument Corp., 107 Goundry St., North Tonawanda, N. Y.

CIRCLE 423 ON READER-SERVICE CARD

PRESSURE TRANSDUCER. 4-page brochure describes TP-200 pressure transducers for measuring absolute, gage, or differential pressures from 0-5 to 0-500 psi full-scale.—Fairchild Controls Corp., 225 Park Ave., Hicksville, L. I., N. Y.

CIRCLE 424 ON READER-SERVICE CARD

PRESSURE TRANSDUCER. 2-page Bulletin DPS/A10 details DX-100 Series Digital Pressure Transducer.—Datex Corp., 1307 S. Myrtle Ave., Monrovia, Calif.

CIRCLE 425 ON READER-SERVICE CARD

TIME, SPEED, COUNT

IMPULSE COUNTER. 4-page Bulletin N-310 describes Series 310 Automatic Reset Impulse Counter.—Automatic Timing & Controls, Inc., King of Prussia, Pa.

CIRCLE 426 ON READER-SERVICE CARD

TACHOMETERS. 2-page bulletin describes Size 11 d-c Tachometers.—Kearfott Div., General Precision, Inc., Little Falls, N. J.

CIRCLE 427 ON READER-SERVICE CARD

COUNTERS. 6-page Catalog 608.462 lists electric, stroke, turn, revolution and coil winding counters.—Automation Controls Div., General Controls Co., 8080 McCormick Blvd., Skokie, Ill.

CIRCLE 428 ON READER-SERVICE CARD

COUNTERS. 8-page Catalog 200 presents descriptions and prices of industrial counters.—Durant Mfg. Co., 1929 N. Buffum St., Milwaukee 1, Wis.

CIRCLE 429 ON READER-SERVICE CARD

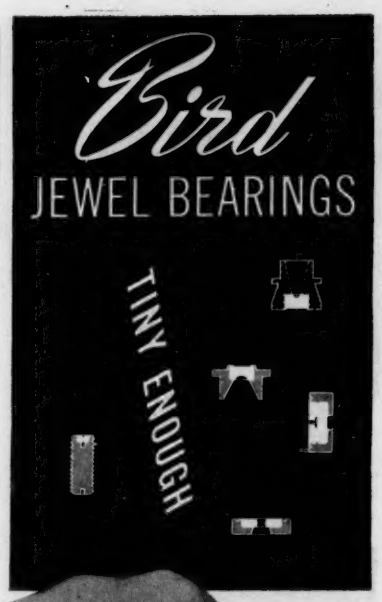
TACHOMETERS, COUNTERS, accessories and related equipment are described in 6-page brochure.—Barbour Stockwell Instruments, Div. Curtis & Marble Machine Co., 80 Cambridge St., Worcester 3, Mass.

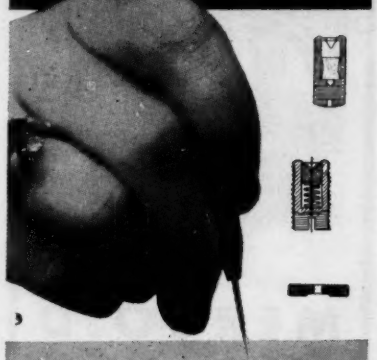
CIRCLE 430 ON READER-SERVICE CARD

PATENTS FOR INVENTORS. 20-page booklet "Preparing for Patent-hood," a booklet about patents for inventors and engineers, is interspersed with cartoons to illustrate the point.—Trak Electronics Co., Div. of CGS Labs., Inc., 49 Danbury Rd., Wilton, Conn.

CIRCLE 431 ON READER-SERVICE CARD

Bird
JEWEL BEARINGS





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Aircraft and electrical instruments, measuring and timing devices, testing and recording equipment — they all require the services of sub-miniature bearings that insure a fine degree of accuracy. Bird Precision Jewel Bearings fulfill this need because they are designed to provide peak accuracy in minimum space.

Available in a wide range of standard glass and sapphire types and sizes, including complete jewel assemblies and cushion jewel assemblies, Bird Jewel Bearings can save you money on your next design. Our engineering staff is at your service to aid you with your special requirements.

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CIRCLE 164 ON READER-SERVICE CARD

When you deal with explosive gases

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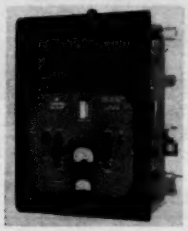
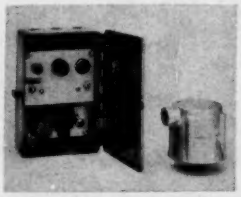
J-W Model RV samples and analyzes air at 2 to 16 locations. Relays information to main analyzer panel. Recording instruments and explosive-proof construction available on order.



J-W Model SM continuously checks one location where accessibility is a problem; alarms at a pre-set level.



J-W Model E detects explosive gases in a single area; control box is remote from sensing unit. Model EE is similar to Model E with units encased in explosion-proof housing.

Do you have a problem with combustible gases that requires a special detection system design? Experienced J-W engineering is available to help you. For complete data on services, please write:

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CIRCLE 165 ON READER-SERVICE CARD

RECORDERS, CONTROLLERS

CONTROLLERS. 56-page Catalog C-15-2a covers line of ElectroniK controllers, pneumatic and electric.—Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Phila. 44, Pa.

CIRCLE 432 ON READER-SERVICE CARD

CONTROLLER. 6-page Bulletin 4411 features SR-4 Pointer Indicator and Indicating Controller for strain gage transducer systems.—Baldwin-Lima-Hamilton, Electronics & Instrumentation Div., Waltham 54, Mass.

CIRCLE 433 ON READER-SERVICE CARD

STRAIN GAGE RECORDING. 4-page Application Note 103 analyzes three general methods of coupling strain gages to X-Y Recorders.—F. L. Moseley Co., 409 N. Fair Oaks Ave., Pasadena, Calif.

CIRCLE 434 ON READER-SERVICE CARD

RECORDERS, CONTROLLERS. Three spec sheets (S 172-1, S 173-1, S 176-1) describe recorders; three spec sheets (S 172-2, S 173-2, S 176-2) describe controllers.—Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne and Windrim Aves., Phila. 44, Pa.

CIRCLE 435 ON READER-SERVICE CARD

RECORDING FLUOROMETER. 2-page data sheet describes Model 111 Self-Balancing Fluorometer, which provides both direct readout and outputs for various types of recorders or controllers.—G. K. Turner Associates, 2524 Pulgas Ave., Palo Alto, Calif.

CIRCLE 436 ON READER-SERVICE CARD

DATA HANDLING

COMPUTER. 20-page Bulletin QC-020-R110 describes basic, medium and large G-20 high-speed computing systems.—Bendix Corp., Computer Div., 5630 Arbor Vitae St., Los Angeles 45, Calif.

CIRCLE 437 ON READER-SERVICE CARD

COMPUTER APPLICATIONS. 4-page Report 15 examines how a Bendix G-15 computer aided research at American Viscose Corp. Two additional reports describe application of G-15 to electricity distribution programs.—Bendix Corp., Computer Div., 5630 Arbor Vitae St., Los Angeles 45, Calif.

CIRCLE 438 ON READER-SERVICE CARD

COMPUTER RECORDER, MODULES. 8-page brochure describes Model S-2010 solid-state Computer Format Recorder. Bulletins 11601 and 11602 describe Transicon Datrac Voltage-to-Digital Converter and Programmable Digital Multimeter.—Epsco Systems, Div. Epsco, Inc., 275 Massachusetts Ave., Cambridge 39, Mass.

CIRCLE 439 ON READER-SERVICE CARD

TAPE-DATA EQUIPMENT. 4-page Short Form Catalog presents Time Code Generators, Timing System Auxiliary Equipment, Magnetic Tape Search and Control Systems, etc.—Electronic Engineering Co. of Calif., 1601 E. Chestnut Ave., Santa Ana, Calif.

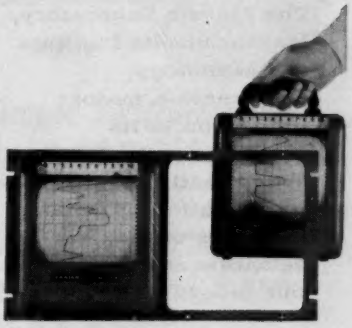
CIRCLE 440 ON READER-SERVICE CARD

ABSOLUTE LEVEL CONTROL. 2-page Bulletin 60-05 describes application of Serva-Levl to maintain absolute level of lathes despite changing load conditions.—Barry Controls Inc., 700 Pleasant St., Glendale, Calif.

CIRCLE 441 ON READER-SERVICE CARD

VARIAN
Potentiometer
RECORDERS

The logical "first choice" because . . .



TOTAL DESIGN IS

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Carry it anywhere — put two side-by-side in a rack. Its shape is ideal for both. And its performance is multi-purpose too: wide choice of ranges, accessories, options and plug-ins. Chances are it has the capability to record for you in a variety of assignments.

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VARIAN associates
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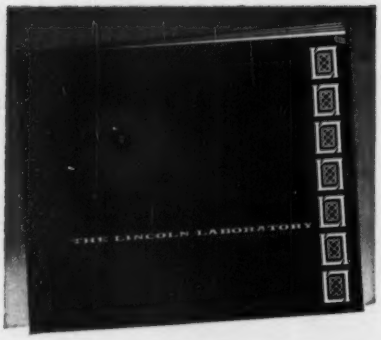

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COMPUTER SIMULATION. 20-page brochure, "New Solutions in the Science of Simulation," details latest advances in computer technology and equipment.—Computer Systems, Inc., Culver Rd., Monmouth Junction, N. J.
CIRCLE 442 ON READER-SERVICE CARD

DIAL-O-VERTER. 8-page brochure describes "Dial-o-verter" System that functions with Bell Data-Phone 200 to send and receive data via regular dial telephone network.—Digitronics Corp., Albertson, L. I., N. Y.
CIRCLE 443 ON READER-SERVICE CARD

TENSIOMETER. 3-page bulletin details Model K-44 Magnetic Tape Tensiometer.—General Kinetics Inc., 2611 Shirlington Rd., Arlington 6, Va.
CIRCLE 444 ON READER-SERVICE CARD

ALPHA-NUMERIC DISPLAY. 2-page Bulletin B262 describes solid-state alpha-numeric display.—Robotomics Corp., 2422 E. Indian School, Phoenix, Ariz.
CIRCLE 445 ON READER-SERVICE CARD

COMPUTER. 74-page Brochure TM8 (11-60) describes Philco 2000 electronic data processing system; 8-page brochure presents 7 new devices available as optional equipment.—Philco Corp., Computer Div., 3900 Welsh Rd., Willow Grove, Pa.
CIRCLE 446 ON READER-SERVICE CARD

COMPUTER. 24-page Bulletin AC 6007 describes and illustrates Model 231R Analog Computer.—Electronic Associates Inc., Long Branch, N. J.
CIRCLE 447 ON READER-SERVICE CARD

CARD READER. 10-page brochure describes Speedreader 2000 that reads 400 to 3,000 cards/min.—Uptime Corp., 175 Commerce St., Broomfield, Colo.
CIRCLE 448 ON READER-SERVICE CARD

COMPUTER COMPONENTS. 2-page condensed catalog sheet covers line of analog computer components.—Embree Electronics Corp., 993 Farmington Ave., West Hartford 7, Conn.
CIRCLE 449 ON READER-SERVICE CARD

AIR

AIR DRYER. 2-page Bulletin 9300 details Series-E Air Dryer.—Hankison Corp., College and Pike, Canonsburg, Pa.
CIRCLE 450 ON READER-SERVICE CARD

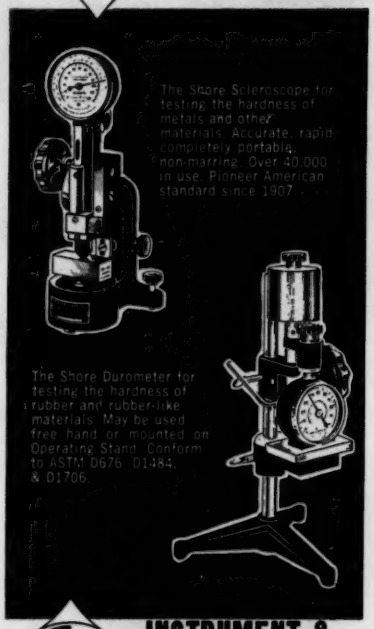
AIR SAMPLING. 3-page Manual 2 describes techniques of measuring dust and gases in air.—Gelman Instrument Co., 106 N. Main St., Chelsea, Mich.
CIRCLE 451 ON READER-SERVICE CARD

ANALYTICAL

AMMONIA ANALYSIS. 4-page data sheet outlines means of securing continuous automatic analysis of ammonia content of boiler waters.—Technicon Controls, Inc., Chauncey, N. Y.
CIRCLE 452 ON READER-SERVICE CARD

SCALER-ANALYZER. 4-page bulletin illustrates and describes the RCLiac 128 which features number and curve display.—Radiation Counter Labs., Inc., Nucleonic Park, 5121 W. Grove St., Skokie, Ill.
CIRCLE 453 ON READER-SERVICE CARD

HARDNESS TESTING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CONSTANT CURRENT
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Model 4005 is a 1-40 volt, 500 ma, regulated DC power supply incorporating AMBITROL.* The AMBITROL* circuit will switch *automatically* to either voltage regulation or current regulation at any point predetermined by the operator, with continuous control of voltage or current to .05%.

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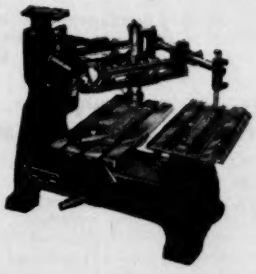

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CIRCLE 170 ON READER-SERVICE CARD

pH METERS. 2-page Bulletin 719-B describes Models G and GS pH Meters (Model GS provides 20 times greater meter sensitivity).—Beckman Scientific and Process Instruments Div., 2500 Fullerton Rd., Fullerton, Calif.

CIRCLE 454 ON READER-SERVICE CARD

COMBUSTION

FLAME DETECTOR. 2-page Bulletin E66-2 describes Flamon Detector which senses presence of flame and operates internal relay or transmits signal to static switch.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

CIRCLE 455 ON READER-SERVICE CARD

COMBUSTION INDICATOR. 8-page Bulletin Q-2 describes Qual-O-Rimeter Combustion Indicator which indicates changes in flame caused by variations in air/gas mixture.—Selas Corp. of America, Dresher, Pa.

CIRCLE 456 ON READER-SERVICE CARD

MISCELLANEOUS

OSCILLOSCOPES. 20-page booklet details "complete-unit" Oscilloscopes.—Tektronix, Inc., Box 500, Beaverton, Ore.

CIRCLE 457 ON READER-SERVICE CARD

TESTING. 4-page catalog describes Model PA Series Dielectric Breakdown Testers.—Industrial Instruments, Inc., 89 Commerce Rd., Cedar Grove, Essex County, N. J.

CIRCLE 458 ON READER-SERVICE CARD

CONSISTENCY REGULATOR. 2-page Bulletin 16C2381 describes Pipeline Consistency Regulator, which regulates and records, on an arbitrary scale, consistency of pulp stock.—Fischer & Porter Co., 802 Jacksonville Rd., Warminster, Pa.

CIRCLE 459 ON READER-SERVICE CARD

PAPER CAPACITORS. 6-page Catalog 131 B8.1 gives characteristics of high-temp metallized paper capacitors.—Aerovox Corp., New Bedford, Mass.

CIRCLE 460 ON READER-SERVICE CARD

BRIDGES, POWER SUPPLIES. 2-page Special Product Note describes Resistance Bridges and Power Supplies for airborne and ground-based applications.—Trans-Sonics, Inc., Box 328, Lexington 73, Mass.

CIRCLE 461 ON READER-SERVICE CARD

POTENTIOMETERS

INDUCTIVE POTENTIOMETERS. 2-page Data Sheet 801-LP4 gives facts on Size 8 inductive potentiometer line.—Daystrom Transicoil Div., Daystrom Inc., Worcester, Montgomery County, Penna.

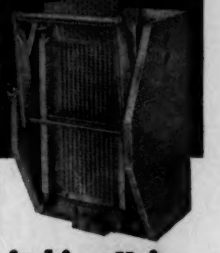
CIRCLE 462 ON READER-SERVICE CARD

PRECISION POTENTIOMETERS. 28-page Catalog POT 359 gives specs, diagrams, and general information on line of single-turn, precision wirewound potentiometers.—DeJur Amsco Corp., Electronic Sales Div., 45-01 Northern Blvd., Long Island City 1, N. Y.

CIRCLE 463 ON READER-SERVICE CARD

TAURUS
PUNCHED CARD SENSORS

Reads Entire Punched Card Statically



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Simple Switching Using Standard Punched Cards

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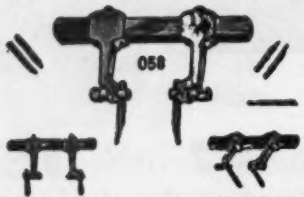

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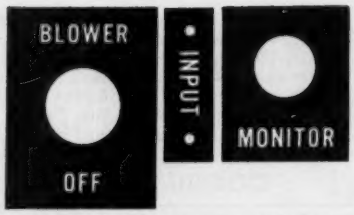

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Centrifugal tachometer that measures revolutions per minute and surface speeds.

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BOOKS

Strain Gage Instrumentation

edited by Aronson and Nelson. ". . . a practical text . . . covers fundamentals, basic bridge circuits, typical applications, and surveys typical commercial instruments which use or are used with strain gages." Paper, 110 pages, illustrated, indexed by company, author, and subject, 1958. **$2.00**

100 Electronic Circuits

by M. H. Aronson and C. F. Kezer . . . covers amplifiers, oscillators, pulse circuits, phase shifters, etc. Complete with all circuit component values and response specifications. Paper, 180 pages, 1957. **$2.00**

Process Control Analysis

by M. H. Lajoy and E. A. Baillif. An essential first step in analysis of closed-loop controlled processes via frequency response of the system. Clothbound, 72 pages, 1956. **$2.00**

Electronic Circuitry for Instruments and Equipment

by M. H. Aronson. "Comprehensive source book on instrument circuitry." this complete home-study text includes 458 multiple-choice questions (and answers), 215 illustrations, 10 tables, comprehensive index. Paperbound, 324 pages, (revised edition). **$2.00**

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INDUSTRY NEWS

John C. Forrest

Dr. F. N. Gillette

L. L. Pourciau

GPL DIVISION of General Precision, Inc. has promoted *John C. Forrest* and *Dr. Frank N. Gillette* to director and associate director, respectively, of the Engineering Division. *Louis L. Pourciau* has been named head of the Industrial Products Department.

GENERAL PRECISION announces that *William H. Reinholtz* has been named chief engineer of the Burbank Branch of **LIBRASCOPE DIVISION.**

W. H. Reinholtz

L. M. Faulkner

L. B. Krumm

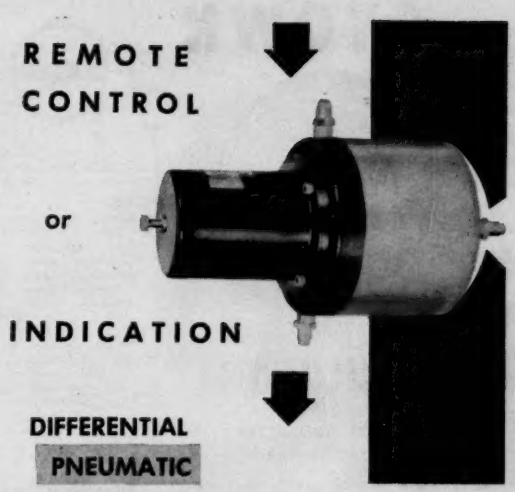
HAGAN CHEMICALS & CONTROLS has named *L. M. Faulkner* manager of utility sales for the Controls Division.

BRISTOL COMPANY has appointed *L. B. Krumm* field sales manager of the Instrument Division.

STATHAM INSTRUMENTS has appointed *R. S. Bowditch* chief engineer of the Electronics Division.

Mr. Lawrence Moskowitz, formerly with Schaevitz Engineering, and author of article on accelerometer calibration in the February and March issues of *Instruments and Control Systems* is now associated with **DYNAMIC MEASUREMENTS CO.**, 301 Old York Rd., Jenkintown, Penna.

ESTERLINE-ANGUS is doing a $100,000 remodeling job at its office building to beautify and modernize its facilities.



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AUGUST

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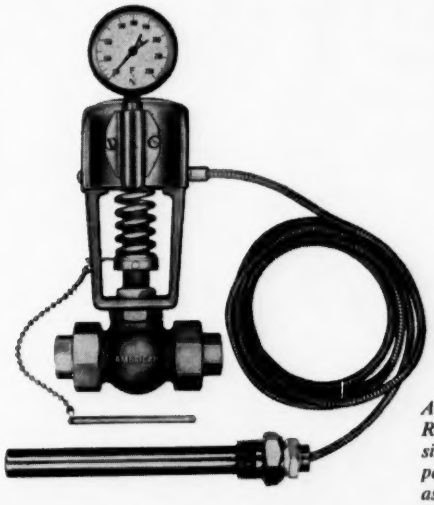

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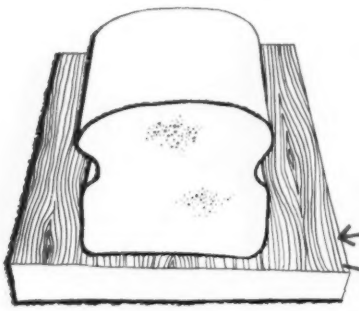

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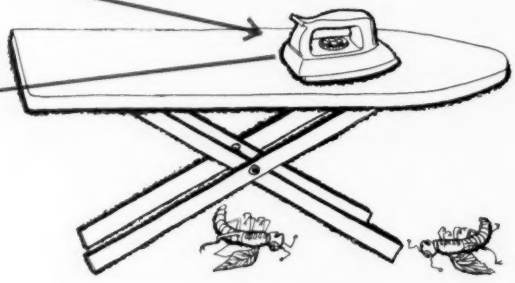

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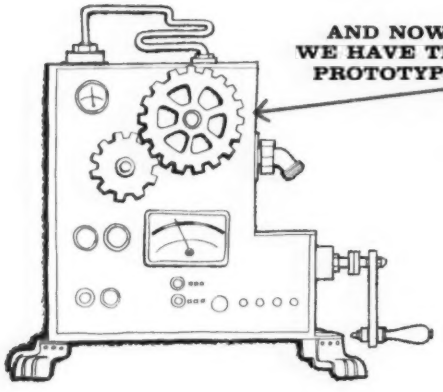

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